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SERIE: HYDROGRAFI · BIND I

Nr. 7. J. N. Nielsen: CONTRIBUTIONS TO THE HYDROGRAPHY OF THE WATERS NORTH OF ICELAND. (WITH 2 PLATES)

Nr. 8. J. P. Jacobsen: DIE LÖSLICHKEIT VON SAUERSTOFF IM MEERWASSER DURCH WINKLERS TITRIERMETHODE BESTIMMT

KØBENHAVN
I KOMMISSION HOS C. A. REITZEL
BIANCO LUNOS BOGTRYKKERI
1905

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CONTRIBUTIONS

TO THE

HYDROGRAPHY OF THE WATERS NORTH OF ICELAND

BY

J. N. NIELSEN

(WITH 2 PLATES)

KØBENHAVN
I KOMMISSION HOS C. A. REITZEL
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CONTENTS

	Page
Introduction	3
Material of Observation	4
Discussion of the Sections	7
Concluding Remarks	27

Map Showing the Stations and Sections in 1904	Pl. I
Sections in 1904	„ II

Introduction.

During the cruise with the "Thor" in the summer 1903 our researches in the waters north of Iceland were very scarce, as only one series of stations (June, 1903) were taken, and as these were situated so close to the coast and, at the same time, in so shallow water that they could not give an ample picture of the conditions in these waters. As, furthermore, these stations were taken with only short intervals, we cannot draw any conclusions from them as to the hydrographic changes which occur from time to time. That such changes — even of rather considerable proportions — do take place, is seen from the observations of the temperature of the surface water at the meteorological station of observation at Grimsey, the mean temperature of the surface water being in the coldest period (February—March) about 0°, while in the warmest season (August) it is about 8°.

The "Thor" having, in consequence of the programme for the fishery researches in 1904, to pass the north of Iceland 3 times during the summer, I resolved, time permitting, to make the hydrographic changes in these waters the subject of a closer examination, which task I fancied might be accomplished in this way that, besides a series of stations in illustration of the hydrographic conditions on the whole, researches were made, as far as possible, at certain fixed stations by which we got a direct determination of the changes during the time elapsed for these stations.

Such researches were made in April (22.—24.), May 30.—June 2., July 20.—23., and August 12.—24. As mentioned above the chief object of the ship's work during these periods was fishery researches, and so it was not always possible to accomplish the fixed stations, still I must gratefully mention the interest and readiness which the ichthyologist Dr. J. Schmidt showed as to these hydrographical researches, and so it was possible to extend the researches towards the north across the waters of Atlantic origin which towards the close of July were found north of Iceland.

That the researches were not accomplished in the extent which might have been desirable is owing partly to the circumstance that the fishery researches had several important tasks which had necessarily to be concluded, before the projected hydrographical researches in the waters between Iceland and the Faroe Islands should be commenced, partly to the fact that the work was checked or even quite prevented by the unsettled weather. When towards the end of April we passed north of the country, we had constantly a hard western gale, which highly impeded our work, and when we were sailing north of Iceland the second time a tempestuous northern gale with a highly agitated sea prevented all depth measurings on the range from Røde Huk to Cape North so that we could here only make surface observations. Towards the close of July when Section VI (from Grimsey towards the north) was taken, it came again up to blow with a hard western gale and rain, so that the indications of place for the two northmost stations (76 and 77) are rather uncertain.

As to the apparatus used and the accomplishment of the measurings we refer to "Bulletin des résultats acquis pendant les courses périodiques", May and August 1904, and "Meddelelser fra Kommissionen for Havundersøgelser", Serie: Hydrografi, Bind I, Nr. 4 (Køb. 1904).

Material of Observation.

The material of observation from the stations in the waters north of Iceland is noted in the following Table I. m means the depth measured in meters, $t°$ the corrected temperature in centigrades, S‰ the salinity in pro mille, and σ_t is an expression for the specific gravity s_t, calculated by temperature and salinity, which is not corrected for pressure. $\sigma_t = 1000\ (s_t - 1)$.

The examined samples of surface water are noted in Table II.

The sections are drawn according to the scale used for sections in "Bulletin des résultats etc.", that is: 1^{mm} represents 2 Kilometers in horizontal direction, and 5 meters in vertical direction; only in Section IV the half scale is applied in vertical direction (1^{mm} represents 10 meters).

Table I.

m	$t°$	S‰	σ_t
Station **10** 1904 IV 22 66°17′ N Lat. 23°14′ W Long. 125 m.			
0	1·42	34·69	27·78
50	2·82	99	92
120	94	35·05	95
Station **11** 1904 IV 23 66°33′ N Lat. 23°37′ W Long. 84 m.			
0	2·40	34·97	27·94
82	97	—	—
Station **12** 1904 IV 23 66°31′ N Lat. 22°25′ W Long. 62 m.			
0	1·20	34·76	27·86
40	05	81	92
60	05	81	92
Station **13** 1904 IV 23 66°30′ N Lat. 20°47′ W Long. 220 m.			
0	2·34	34·94	27·92
25	41	96	92
50	47	97	94
100	46	97	94
210	68	99	93
Station **14** 1904 IV 23 66°32′5 N Lat. 17°50′ W Long. 175 m.			
0	1·50	34·85	27·90
25	65	87	91
50	68	87	91
100	70	85	89
170	70	87	91
Station **15** 1904 IV 24 66°09′ N Lat. 14°26′ W Long. 178 m.			
0	0·63	34·70	27·85
25	74	72	86
50	73	72	86
100	71	72	86
175	66	74	88

m	$t°$	S‰	σ_t
Station **49** 1904 V 30 66°30′ N Lat. 14°54′ W Long. 133 m.			
0	3·19	34·42	27·41
10	2·48	51	56
25	1·35	72	82
50	07	72	84
75	05	72	84
100	04	72	84
130	0·87	74	87
Station **50** 1904 V 31 66°35′5 N Lat. 16°31′ W Long. 81 m.			
0	4·30	33·73	26·76
10	3·09	34·20	27·27
25	1·32	70	81
50	29	70	81
80	27	74	84
Station **51** 1904 VI 2 66°29′ N Lat. 22°25′ W Long. 62 m.			
0	3·52	34·67	27·59
10	49	67	59
25	49	70	62
60	49	70	62
Station **52** 1904 VI 2 66°20′ N Lat. 23°31′ W Long. 142 m.			
0	4·25	34·92	27·71
10	24	92	71
25	17	98	77
50	19	99	78
75	25	99	77
100	34	35·01	78
140	37	01	78

m	$t°$	S‰	σ_t
Station **53** 1904 VI 2 66°05′5 N Lat. 23°42′ W Long. 27 m.			
0	4·95	33·64	26·62
5	36	34·02	99
10	16	18	27·14
25	05	31	25
Station **54** 1904 VI 17 65°51′5 N Lat. 23°56′ W Long. 58 m.			
0	7·02	34·40	26·96
10	6·55	38	27·02
25	50	49	10
40	39	61	22
45	39	61	22
47·5	5·89	54	22
50	2·21	—	—
55	16	51	59
Station **55** 1904 VI 18 65°53′ N Lat. 24°59′ W Long. 82 m.			
0	6·89	34·74	27·25
10	88	74	25
17·5	55	78	32
25	5·90	85	46
50	85	87	49
80	84	87	49
Station **56** 1904 VI 18 65°52′ N Lat. 26°12′ W Long. 275 m.			
0	7·19	35·07	27·46
10	19	08	47
25	6·99	08	50
50	95	11	53

m	$t°$	S‰	σ_t
75	6·61	35·10	27·57
100	15	16	68
150	00	14	69
200	5·81	14	72
270	75	14	72
Station **57** 1904 VI 18 65°50′ N Lat. 26°53′ W Long. 392 m.			
0	7·40	35·14	27·49
10	29	14	51
25	24	14	52
50	18	14	53
75	6·56	16	62
100	25	16	66
200	13	16	68
300	5·86	16	71
350	84	17	72
390	83	17	72
Station **58** 1904 VI 19 65°00′ N Lat. 28°10′ W Long. 1230 m.			
0	8·29	35·16	27·37
10	21	16	39
25	7·59	16	48
50	50	16	49
75	6·81	16	59
100	53	16	63
200	37	16	65
300	27	16	66
400	20	16	67
600	5·77	10	69
800	18	10	76
1000	4·40	01	78
1225	07	03	82

m	$t°$	S ‰	σ_t
Station 59 1904 VI 20			
65°21′ N Lat. 26°50′ W Long. 768 m.			
0	7·86	35·08	27·38
10	59	08	42
30	09	10	51
50	6·95	10	53
100	40	12	61
200	15	12	65
400	5·09	02	70
500	1·76	34·70	78
600	0·21	72	89
765	04	92	28·08
Station 60 1904 VI 21			
65°27′ N Lat. 27°10′ W Long. 617 m.			
0	7·70	35·09	27·41
100	6·52	12	60
400	14	11	64
600	5·83	11	68
»	83	11	68
Station 61 1904 VI 26			
65°32′ N Lat. 24°34′ W Long. 41 m.			
0	8·17	34·13	26·58
5	7·93	25	71
10	77	34	82
20	66	50	95
40	61	52	97
Station 70 1904 VII 20			
66°17′ N Lat. 14°27′ W Long. 81 m.			
0	7·19	34·11	26·71
10	6·56	18	85
25	5·39	45	27·21
40	4·14	58	46
60	3·86	61	53
80	32	67	61
Station 71 1904 VII 20			
66°25·5 N Lat. 14°51′ W Long. 57 m.			
0	8·59	33·82	26·29
10	7·31	34·13	70
25	5·49	58	27·30
40	3·84	70	59
55	21	76	69

m	$t°$	S ‰	σ_t
Station 72 1904 VII 21			
66°36·5 N Lat. 16°18′ W Long. 78 m.			
0	9·74	3315	25·58
5	8·85	—	—
10	7·89	77	26·34
15	24	—	—
25	5·82	34·69	27·34
40	4·61	76	56
60	12	82	65
75	00	84	67
Station 73 1904 VII 21			
66°14′ N Lat. 17°28′ W Long. 197 m.			
0	10·50	31·62	24·25
10	7·12	34·11	26·73
17	6·52	43	27·06
25	74	69	22
50	5·95	76	39
75	37	88	56
100	4·84	96	68
125	39	94	72
150	23	92	72
195	30	97	76
Station 74 1904 VII 21			
66°33′ N Lat. 18°10′ W Long. 75 m.			
0	8·40	33·91	26·38
10	7·49	34·79	27·21
17	19	85	30
21	6·34	—	—
25	5·49	82	50
50	06	87	58
73	4·81	88	62
Station 75 1904 VII 22			
66°52′ N Lat. 18°10′ W Long. 400 m.			
0	8·23	34·78	27·09
10	7·87	—	—
25	5·91	97	57
50	22	35·03	70
75	4·70	—	—
100	21	34·97	77
200	3·61	97	83
300	2·50	96·5	93
350	1·04	95	28·02
400	0·23	96	08

m	$t°$	S ‰	σ_t
Station 76 1904 VII 22			
67°02′ N Lat. 18°10′ W Long. 322 m.			
0	6·90	34·81	27·31
25	38	83	40
35	4·82	83	58
50	57	85	62
75	3·02	88	81
100	2·38	87	86
150	1·90	87	90
200	0·58	83	96
300	29	92	28·04
Station 77 1904 VII 22			
67°19′ N Lat. 17°55′ W Long. 820 m.			
0	6·11	34·70	27·33
25	4·30	70	54
50	2·41	72	73
100	0·24	72	89
150	1·06	83	93
200	0·37	85	98
300	51	92	28·03
400	36	92	04
500	10	94	07
600	—0·13	94	09
800	— 43	93	09
Station 78 1904 VII 23			
66°15′ N Lat. 12°13′ W Long. 624 m.			
0	6·95	34·49	27·04
10	68	48	07
17·5	00	49	17
25	4·51	61	45
32·5	3·15	—	—
40	2·85	80	76
50	00	81	85
55	32	—	—
60	40	—	—
75	47	89	87
100	42	92	89
150	27	91	90
200	1·80	88	91
250	41	85	91
300	04	87	96
400	0·19	90	28·04
500	—0·20	92	07
610	— 40	92	08

m	$t°$	S ‰	σ_t
Station 99 1904 VIII 12			
66°10′ N Lat. 14°29′ W Long. 189 m.			
0	7·60	34·43	26·89
10	53	44	92
25	6·90	51	27·06
50	5·89	69	33
75	20	78	50
100	4·61	85	62
150	22	87	68
185	3·87	90	74
Station 100 1904 VIII 13			
66°16′ N Lat. 13°36′ W Long. 284 m.			
0	8·57	34·51	26·82
10	31	51	86
17	17	—	—
25	6·00	69	27·32
35	4·87	—	—
50	3·58	88	75
75	32	91	80
100	08	92	83
150	2·58	89	86
200	00	88	90
240	01	—	—
275	1·98	90	92
Station 101 1904 VIII 14			
66°20′ N Lat. 12°10′ W Long. 785 m.			
0	7·90	34·61	27·01
15	42	61	08
25	4·61	79	57
35	3·78	85	70
50	2·46	82	81
75	40	81	81
100	62	89	85
200	50	92	89
300	1·91	87·5	90
400	0·72	87·5	98
500	00	92	28·06
750	—0·60	92	09
Station 102 1904 VIII 14			
66°22′ N Lat. 14°11′ W Long. 72 m.			
0	7·92	34·47	26·89
10	6·70	—	—
15	35	61	27 23
25	5·87	72	37
50	4·80	87	61
70	78	87	61

m	$t°$	$S‰$	σ_t
Station 103 1904 VIII 14			
66°30′ N Lat. 15°32′ W Long. 142 m.			
0	8·95	34·13	26·46
25	7·13	76	27·23
50	5·51	90	56
100	14	94	63
135	4·92	94	66
Station 104 1904 VIII 15			
66°14′ N Lat. 17°28′ W Long. 226 m.			
0	8·60	34·27	26·62
10	52	27	64
25	7·84	47	90
35	6·71	60	27·16
50	5·90	82	44
75	63	86	50
100	40	91	58
150	31	96	·62
190	4·85	34·93	27·66
220	61	99	73
Station 105 1904 VIII 22			
66°13′ N Lat. 18°43′ W Long. 51 m.			
0	7·02	33·49	26·25
5	05	—	—
10	81	87	44
15	8·09	—	—
25	13	34·27	70
50	00	34	78
Station 106 1904 VIII 23			
66°19′ N Lat. 20°38′ W Long. 222 m.			
0	4·50	32·18	25·51
10	70	94	26·09
17·5	5·65	33·53	45
25	6·30	33·89	26·66
30	11	93	71
37·5	4·42	95	92
50	27	34·34	27·26
62·5	5·45	75	45
75	62	83	49
90	84	94	55
100	6·12	35·05	60
150	5·90	07	64
215	82	07	65
Station 107 1904 VIII 24			
66°30′ N Lat. 22°27′ W Long. 46 m.			
0	8·91	34·58	26·82
10	96	58	82
20	93	58	82
30	91	58	82
45	72	61	88
Station 108 1904 VIII 24			
66°19′ N Lat. 23°27′ W Long. 115 m.			
0	9·42	34·67	26·81
10	52	66	78
25	46	66	79
35	39	—	—
50	8·16	85	27·15
75	7·37	91	31
110	6·76	35·01	48
Station 109 1904 VIII 26			
65°29′ N Lat. 24°37′5 W Long. 43 m.			
0	10·26	34·54	26·57
10	20	54	58
15	20	53	57
25	21	54	58
40	21	57	60

Table II.

Time	N Lat.	W Long.	Surf. temp.	Surf. salin.
1904				
IV 22	66°11′	23°11′	1·00	34·56
» »	17′	14′	42	69
» 23	33′	37′	2·40	97
» »	31′	22°25′	1·20	76
» »	30′5	21°41′	3·12	35·07
» »	30′	20°47′	2·34	34·94
» »	32′5	17°50′	1·50	85
» 24	32′	16°48′	10	60
» »	28′	15°48′	0·98	42
» »	17′5	14°30′	1·00	60
» »	09′	26′	0·63	70
» »	65°45′	15′	1·00	61
» »	27′	13°30′	00	58
V 30	66°30′	14°54′	3·19	42
» 31	32′	15°42′	2·94	56
» »	35′	16°31′	4·30	33·73
» »	16′	17°06′	68	96
VI 1	12′	18°08′	51	57
» »	14′	37′	2·00	34·51
» 2	17′	19°22′	4·01	33
» »	17′	59′	3·61	88
» »	17′	20°37′	4·15	78
» »	17′	21°14′	3·80	97
» »	23′	48′	63	90
» »	29′	22°25′	52	67
» »	20′	23°31′	4·25	92
» »	05′5	42′	95	33·64
» 17	65°51′5	56′	7·02	34·40
» »	56′	24°01′	6·78	20
» »	55′	10′	7·20	70
» »	55′	22′	6·90	85
» »	54′	37′	66	88
» »	53′	45′	55	88
» 18	53′	59′	89	74
» »	53′	25°20′	57	99
» »	52′	32′	7·34	35·04
» »	52′	54′	20	03
» »	52′	26°12′	19	07
» »	50′	53′	40	14
» »	37′	27°10′	35	14
» 19	25′	30′	65	16 5
» »	12′	52′	70	15
» »	00′	28°10′	8·29	16
1904				
VI 20	65°21′	26°50′	7·86	35·08
» 21	27′	27°10′	70	09
» »	31′	26°30′	69	—
» 22	32′	21′	50	03
» »	35′	00′	51	34·99
» »	28′	25°48′	58	35·02
» »	28′	25′	76	34·52
» 26	32′	24°34′	8·17	13
VII 19	18′5	13°41′	7·5	31·4
» »	27′	34′	0	34·0
» 20	35′	40′	6·18	—
» »	41′	14°09′	7·68	18·57
» »	50′	11′	6·80	34·36
» »	66°01′	17′	50	—
» »	11′	24′	32	09
» »	17′	27′	7·19	11
» »	25′5	51′	8·59	33·82
» »	29′	15°22′	52	34·25
» »	31′	46′	42	07
» »	36′5	16°10′	9·43	33·22
» 21	36′5	18′	74	15
» »	14′	17°28′	10·50	31·62
» »	20′	41′	9·80	34·40
» »	27′	54′	35	56
» »	33′	18°10′	8·40	33·91
» 22	43′	10′	39	34·63
» »	52′	10′	23	78
» »	67°02′	10′	6·90	81
» »	09′	17°55′	7·07	81
» »	19′	55′	6·11	70
» »	11′	17′	7·04	83
» »	03′	16°41′	86	51
» 23	66°54′	02′	47	36
» »	45′	15°22′	15	40
» »	38′	14°46′	94	—
» »	29′	09′	36	—
» »	21′	13°34′	6·90	47
» »	16′	00′	7·10	51
» »	15′	12°13′	6·95	49
» 24	00′	36′	68	61
» »	65°47′	13°00′	68	34
» »	40′	14′	7·06	33·69
» 25	32′	30′	6·90	34·14
1904				
VIII 13	66°09′	14°46′	8·6	—
» »	10′	29′	25	34·43
» »	12′	04′	62	29
» »	16′	13°36′	57	51
» »	18′	12′	50	49
» »	19′5	12°47′	52	36
» »	21′5	23′	48	45
» 14	20′	10′	7·90	61
» »	21′5	35′	8·30	38
» »	22′	13°00′	40	48
» »	23′	25′	42	50
» »	24′	49′	76	30
» »	22′	14°11′	7·92	47
» »	23′	25′	6·85	54
» »	25′5	51′	8·26	25
» »	28′	15°15′	90	18
» »	30′	32′	95	13
» 15	38′	16°18′	59	33·19
» »	14′	17°28′	60	34·27
» »	14′	51′	07	38
» »	13′5	18°16′	9·03	33·28
» »	09′	51′5	8·70	—
» 22	13′	43′	7·02	49
» »	17′	19°15′	4·31	31·94
» »	17′	39′	5·20	32·41
» 23	17′	20°00′	4·7	31·92
» »	16′	07′	6·24	32·48
» »	19′	38′	4·50	18
» 24	05′	21°14′	8·57	34·04
» »	10′	16′	69	—
» »	15′	18′	5·52	32·66
» »	20′	19′	50	—
» »	23′	21′	30	31·98
» »	24′	30′	4·00	—
» »	24′5	38′	9·20	34·56
» »	26′	56′	20	—
» »	27′	22°10′	58	52
» »	30′	27′	8·91	58
» »	29′	55′	9·50	38
» »	23′	23°14′	80	11
» »	19′	27′	42	67
» 25	10′	38′	10·00	47
» 26	65°29′	24°37′5	26	54

Discussion of the Sections.

Section I.

This section, which was taken in the days from April 22.—24. and comprises the stations 11—15 incl., goes in the direction from west to east along the whole northern coast of Iceland, St. 15, however, is situated a few miles south of Langanæs in the Bakkafjordsdeep. Excepting St. 12 which was taken a few miles off shore at Cape North, all the stations are situated at some distance from the shore. Furthermore St. 11 is situated a little west of the shore on the slope towards the Isafjordsdeep.

As the temperature of the air over these waters even as late as the end of April was about 0° the condition must be supposed to be the one characteristic for the winter, and, therefore, we shall enter more fully upon it.

First we observe the lower temperature at the stations which are nearest the shore than at those lying farther away. We see that the temperature at St. 12 (near Cape North) is more than 1° lower than at the stations 11 and 13 on both sides of it. There is also at St. 10 (Table I) in the mouth of the Isafjord a temperature in the surface of 1°42, that is 1° less than at St. 11 which is a little farther (about 15 miles) out at sea, while the bottom water at the two stations has quite the same temperature. There is no doubt that the volumes of water which are found at these stations are of quite the same origin, and the difference of temperature must then chiefly be owing to a greater cooling of the water near the coast than farther out at sea.

We shall, therefore, here mention the factors, different according to the seasons, which are prevailing at the shore of a more extensive continent with ample wet weather and low temperature in winter.

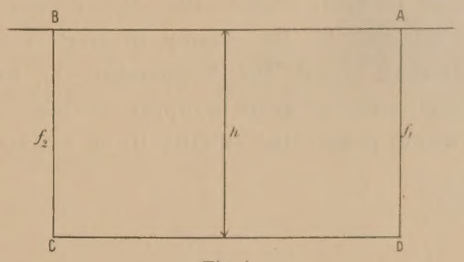


Fig. 1.

Let the figure represent a perpendicular section through the sea, squarely on the shore, A a station near the shore and B farther at sea. Let us observe a square unit at a depth of h under the surface. The condition of equilibrium at this depth is then:

$$h \cdot f_1 \cdot g_1 = h \cdot f_2 \cdot g_2$$

where f_1 and f_2 are the mean values of the specific gravity and g the acceleration of gravity, or when, in order to be plainer, we suppose that both the stations are lying on the same latitude, and the depth of them is the same:

$$hf_1 = hf_2$$

which is to say that the conditions of equilibrium are: that the mean value of the specific gravity of the water volume shall be the same. If f_1 is smaller than f_2 the pressure in the depth h will be greater at C than at D, which will effect an under current from C to D, the consequence of which will be that the surface at A will be lifted over the equilibrium figure answering to that of the surface of the sea whereby is caused a surface current from A to B. If, conversely, $f_2 < f_1$ the pressure will be greater in D than in C, the under current will go from D to C and the surface current from B to A. We have here supposed that the equilibrium surfaces were parallel with the surface but we get the same result when we consider the variation of the gravity and look for the condition of the same pressure in different points of the equilibrium surfaces answering to the real distribution of gravity.

These conditions act an important part as to the movements of the water under a coast, especially in places with a cold winter climate. In summer when the supply of fresh water from rivers and streamlets is ampler on account of the melting of the ice and snow, the water under the coast, on

account of the high mixture with fresh water, gets considerably lighter than the more saliferous water farther out at sea, and its surface will stand higher than the equilibrium figure, from which follows that the lighter coast water will flow away from the shore as a surface current, and that a current towards the shore along the bottom will try to level the differences of specific gravity.

This surface current from shore is proved not only by a lower salinity of the surface water but also by the fact that it carries the pelagic fry from the spawning beds on the shore banks across larger depths, which has already been mentioned, as to Norway, by Dr. HJORT[1]), and which was also proved by Dr. SCHMIDT on the southeastern coast of Iceland where such pelagic fry was found over depths of about 1000 meters. When such pelagic fry in a certain state of development give up their pelagic existence in order to go downward towards the bottom they avoid the influence of this surface current, and it is probable that the greater part of this fry is carried back to the shore banks by the reaction current in the lower layer.

In winter, when the temperature on shore is lower than at sea and the greater part of the wet at the continent is bound in the form of ice and snow, the water under the coast — in consequence of the lower temperature on shore — will be cooled faster than the water at sea, and this cooling will take place quickly because the surface water will sink on account of the greater specific gravity caused by the cooling, whereupon it is partly replaced by other water volumes which will also be cooled and sink.

Thus we get a greater specific gravity in the shore water than in the surrounding sea, and so the opposite current system will arise to that which was found during the summer: a surface current towards shore and an under current off from shore.

The fact mentioned here is certainly the reason why the water nearest the shore around Iceland was in April considerably colder than a little farther out at sea. As to South Iceland it might partly be explained by the supply of fresh water with a temperature about the freezing point, but as to North Iceland where the temperature of the sea water is so low beforehand this factor is confined to a minimum, as such a supply of fresh water, which should have so great an influence on the temperature would reduce the salinity in an extremely high way.

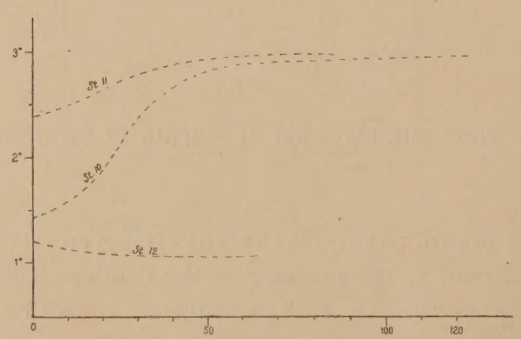


Fig. 2.

In Fig. 2 the distribution of temperature is represented graphically for the three stations 10, 11 and 12; the abscissa indicates the depth, the ordinates the temperature. While at St. 11 the temperature rises from 2°40 in the surface to 2°97 at the bottom, the temperature at St. 10 is only 1°42 in the surface and 2°82 at the depth of 50 meters from which it rises slowly towards the bottom where it assumes the value of 2°94 (120 m.). The above mentioned faster cooling near the shore has thus not urged itself to depths greater than 50 m., but we must remember that here we have an uncommonly great depth for a station being so near the shore, and that such a great amount of warmth is accumulated in the under layer that it is scarcely given off before it is supplied by that of other water volumes[2]), and — which is probably the most important reason — we have further a somewhat lower salinity in the surface (34·69 ‰ in the surface, 34·99 ‰ at the depth of 50 m.), which causes that the surface water in spite of its lower temperature is still lighter than the warmer and salter water beneath, so that the convection currents arising from the cooling of the surface cannot prevail direct by

[1]) F. HJORT: Fiskeri og Hvalfangst i det nordlige Norge. Bergen 1902.

[2]) Compare JOHS. SCHMIDT: Fiskeriundersøgelser ved Island og Færøerne i 1903. p. 58.

the cooling of the under layer, but this cooling must chiefly take place by conduction, a process which takes place much slower than the cooling by convection.

At St. 12 near Cape North we find low temperatures, only a little more than 1°, to the very bottom (60 m.), but the salinity is also rather great here (34·76—34·81 ‰), from which we see that the water is also here of prevalent Atlantic origin, and that the lower temperature arises from loss of heat to the atmosphere. That the distribution of temperature is deviating from that of the other stations is no wonder, when we remember that the station has been taken just off a prominent point past which the tide current is running with a very considerable speed, and where often, when wind and current are contrary, a violent surf arises, which causes an intense mixture of the whole not very thick water layer. The dilution which, though only slightly, takes place near the coast (the surface water at St. 10) is here seen to prevail to the bottom, which also indicates such a mixture.

St. 13 which is situated in the Skagestrandsdeep at a distance of about 25 miles from the nearest land shows similar conditions as St. 11. The temperature as well as the salinity is only a little lower than at the latter, and both are also increasing downward, the temperature from 2°34 in the surface to 2°68 at the bottom (210 m.), while the salinities are respectively 34·94 ‰ and 34·99 ‰. A little west of this station a surface test shows even a strikingly high temperature, 3°12, and a salinity of 35·07 ‰, which shows that the waters of the Irminger current in practically speaking undiluted state may pass Northwest Iceland as a surface current, as the standard value of the salinity in the surface of the Atlantic water in the northern part of the Denmark Strait may be put to 35·10 ‰ according to our observations in June 1903 and June 1904. It is, however, possible that the salinity in June is a little less than in winter but we have no informations as to that. For the part of our place of researches situated between the Faroe Islands and Iceland the maximum of salinity according to the observations on the Iceland routes occurs in March—April, and the minimum in October[1]), and it is probable that the like conditions prevail in the Denmark Strait.

From St. 13 the fall of temperature is faster towards the east to St. 14 near Grimsey than from St. 11 to St. 13. The following table will show the decrease of temperature from St. 13 to St. 14:

Depth (Meter)	Temperature St. 13	Temperature St. 14	Fall of temperature
0	2·34	1·50	0·84
25	2·41	1·65	0·76
50	2·47	1·60	0·79
100	2·46	1·70	0·76
210 (170)	2·68	1·70 (170 m.)	0·98

The salinity is also less, about 0·10 ‰, but still it has a value of 34·85—34·87 ‰. The decrease of temperature thus appears to arise chiefly from loss of heat to the atmosphere, while the mixture with colder water has acted a more inferior part, as such a mixture on account of the low salinity of the polar water would have a considerably greater influence on the salinity of the mixed product, when the temperature of the latter should be the one found here.

We further observe that the temperature at St. 14 is quite the same in the depths of 100 and 170 meters, while at St. 13 we had a rise of temperature of 0°22 from the depth of 100 to 210 meters. This is possibly owing to the fact that the water volumes found east of Grimsey have moved over the shallow on which the isle is situated, and there assume the same temperature everywhere, still it is more probable (compare p. 19) that they have moved across colder water layers or have been partly mixed with the beforehand occurring colder waters.

[1]) Martin Knudsen: Contribution to the Hydrography of the North Atlantic Ocean.

East of Grimsey the surface temperature is fast sinking to about 1°, and it keeps nearly constant until Langanæs, but south of Langanæs we find a temperature about 1 degree lower. The difference of temperature will be seen from the following table:

Depth (Meter)	Temperature St. 14	Temperature St. 15	Diff.
0	1·50	0·63	0·87
25	1·65	0·74	0·91
50	1·68	0·73	0·95
100	1·70	0·71	0·99
170 (175)	1·70	0·66	1·04

Though the temperature at St. 15 in itself must be said to be low, it still gives a secure proof that the water at this station has also been subject to Atlantic influences. In the proper East-Icelandic polar current, which we might expect to find here, a rather fast decrease of temperature takes place from the surface downward, and — which is especially characteristic — there is a minimum of temperature a little below the surface with a temperature below 0°. Now the depth at this station is perhaps too low to reach this minimum, but an indication of it might certainly be expected, at least a negative temperature, but we have on the contrary a maximum and then almost a quite constant temperature. In the East-Icelandic polar current the salinity furthermore increases rather fast from the surface downwards and is rather low in the surface (33—34 ‰), but here we have an almost constant salinity 34·70—34·74 ‰. The distribution of temperature as well as of salinity thus points to an influence of Atlantic water.

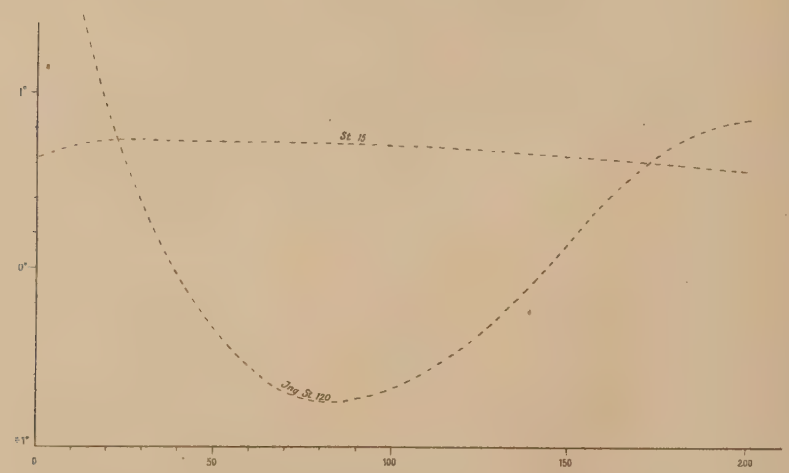


Fig. 3.

In order to show this graphically we have in Fig. 3 represented the distribution of temperature at St. 15 and St. 120 of the Ingolfexpedition, which is situated on 67°29′ north latitude 11°32′ west longitude, and shows the qualities characteristic of the East-Icelandic polar current as well in temperature as in salinity. The higher temperature in the surface at Ingolf's St. 120 arises, of course, from the fact that it was taken in a later period, but a little below the surface the conditions are probably rather unaltered since the season in which St. 15 was taken. The difference at the two stations is as the figure proves rather conspicuous.

We have mentioned the state at these stations so minutely, because, as far as we know, it is the first time that researches of this kind have been made so early in the year in these waters, and, on the whole, we only know very little of the winter state in the waters around Iceland, as the seasonal hydrographic researches are not made in winter, because it is thought that the accomplishment of these researches in these, especially in winter, agitated waters would be connected with too great a risk and offer too great difficulties. We shall now try to draw the most important conclusions of the above described state of the separate stations.

We have already mentioned that the temperature as well in the surface as in the depth decreases from west to east, and that the fall of temperature is about 1° from St. 11 off the northwest of Iceland

to St. 14 at Grimsey from whence it again decreases with about 1° to St. 15 south of Langanæs. This temperature decreasing from west to east thus seems to be the standard for these waters, as former observations taken later in the summer[1]) as well as our observations in June 1903[2]) show such a decrease of temperature to the east; and the observations taken later in the summer 1904 further more confirm this fact.

Common to all the stations mentioned here, except St. 12, the special conditions of which have been stated above, is the fact that the temperature has a minimum in the surface and a maximum farther down, or, at all events is increasing downwards from the surface. This indicates that the temperature of these water volumes is higher than that of the atmosphere, that consequently they yield heat to the latter, and thus contribute to increase the winter temperature of North Iceland. How great a part these volumes of water play as a source of heat is, of course, difficult to say, but later on we shall see that it is rather important.

Just as the temperature is least in the surface, the same is the case with the salinity, but while as to the temperature it is a peculiarity in consequence of the season, this state is the standard one for the salinity; the increase of the salinity downwards is, however, quite insignificant. Thus the difference of the salinity at the bottom and in the surface is for St. 12: 0·05 ‰, for St. 13: 0·05 ‰, for St. 14: 0·02 ‰, and for St. 15: 0·04 ‰. While thus the variations of salinity are small in vertical direction they are of somewhat greater importance in horizontal direction. Thus from St. 13 to St. 14 it decreases with about 0·10 ‰, and from thence to St. 15 with about 0·14 ‰, and we observe that this decrease is quite proportional with the distances, which are respectively 130 and 180 miles. This decrease of the salinity can, consequently, on account of this proportionality not be supposed to arise from a mixture with polar water deficient in salt taking place on a limited territory but must occur quite smoothly and then depend on the 3 following factors: 1) Gradual mixture with the polar water which is found outside the territory of the Irminger current, 2) the wet which in winter is probably greater than the evaporation, and 3) the fresh water coming from the coast which even if this factor plays an inferior part compared with its influence in summer, still cannot be disregarded seeing that the salinities near the coast are somewhat diminished in consequence of this supply of fresh water.

If we consider the distribution of specific gravity we observe that the specific gravity for each separate station is about constant from the surface to the bottom as the diminution of specific gravity arising from the somewhat lower salinity in the surface is compensated for by the lower temperature. These volumes of water are thus in indifferent equilibrium, but the state of equilibrium may so far be called unsettled as a slight cooling of the surface water will cause the latter to assume a greater specific gravity than that of the layer beneath and so will sink downwards, from which vertical currents arise, the socalled convection currents, which will level the differences of specific gravity.

How great a value this difference of specific gravity can assume before such convection currents get important is, of course, difficult to decide, but they seem to prevail as soon as the difference of specific gravity is so great that it is to be proved by our general measuring methods, that is a unit in fifth decimal of the specific gravity, consequently a unit on the last decimal of the values of σ_t indicated in Table I. It is also probable that it rarely exceeds this value, for at such stations where convection undoubtedly takes place we have never found a greater difference of specific gravity than 2×10^{-5} though this phenomenon has often been made the subject of closer examination, and then especially at such stations where the salinity in the surface layer is constant, and where the difference of specific gravity then is only dependent on the temperature. That the salinity is constant means, of course, only that no variation in it can be proved by the method of titration which is used, but if we have a great deal of

[1]) The Danish Ingolf Expedition.

[2]) Medd. fra Kom. fra Havunders. Serie: Hydrografi. Bd. I. Nr. 4. Section XIV.

practice and take the greatest possible pains the errors in the relative values — and it is these which are of importance in this connection — will scarcely exceed 0·01 ‰.

As an instance of such a station where the salinity is constant, and where the cooling from the surface, consequently the distribution of temperature alone, causes convection, we may mention St. *Da Atl* 15 (64° 12′ north latitude 11° 45′ west longitude, May 4. 1904), and we shall here mention all the observations from this station as we may thus see how small the differences in question are.

m	$t°$	S ‰	σ_t
0	7·35	35·25	27·59
10	35	26	60
25	38	26	59
50	38	26	59
75	40	26	59
100	40	26	59
150	40	26	59
200	36	25	59
300	5·93	16	70
375	4·96	03	72

From the distribution of temperature we see that the convection has urged itself to a depth of about 200 meters, though the difference of temperature from the surface to the warmest water at a depth of 75—150 meters is only 0°05 from which follows a difference in σ_t of 0·007, that is a difference of specific gravity of only 7×10^{-6}. This was provided that the salinity was constant; if we suppose that it was up to 0·01 ‰ greater in the surface this gives a difference of specific gravity of $1{\cdot}5 \times 10^{-5}$ in all.

When at these stations situated north of Iceland we have so great an increase of temperature from the surface to the bottom, f. inst. at St. 13 0°34, this can only occur, when the salinity is a little lower in the surface than at the bottom, a condition which exists as mentioned before. This difference in the salinity is, however, so insignificant that it cannot prevent convection currents and so protect the under layer against cooling, but the whole water layer will on the contrary by continued cooling of the surface on account of the arising of these convection currents be able to deliver all its warmth to the atmosphere and thus exercise a great influence on the temperature of the air on North Iceland.

We can now sum up the facts set forth above in the following résumé. In the winter of 1904 the polar ice never reached the coasts of Iceland — its distance from the northwest point of Iceland is indeed unknown[1]) — and consequently there has been a passage open for the warm Atlantic water from the Denmark Strait, the socalled Irminger current. Part of it — the eastern branch of the Irminger current — makes its way past the northwest point of Iceland and turns towards the east along the north coast of Iceland. At the western part of the latter its salinity is about 35·00 ‰ and almost constant from the surface to the bottom, from which we conclude that this current has a not slight breadth, as no perceptible supply of polar water deficient of salt from the East-Greenlandic polar current takes place even in the surface. The temperature is about 3° C., a little lower in the surface, because the water delivers warmth to the colder atmosphere — a condition which must indeed be supposed to prevail in the whole Denmark strait.

The volumes of water then move on towards the east along the north coast of Iceland, and the cooling on account of the loss of heat to the atmosphere is continued so that the temperature de-

[1]) Nautical-Meteorological Annual 1904.

creases from west to east while its vertical distribution remains almost unaltered, as a further cooling of the surface water in proportion to the water layers lying beneath effects convection currents by which even the bottom water will be able to yield its heat to the atmosphere. On account of the lower temperature over land this effect will be strongest nearest land, and so, as mentioned page 8, there arises a tendency to a surface current directed towards land, the opposite of the condition in summer.

While the temperature of these water volumes is decreased on their way towards the east their salinity also grows a little smaller and this decrease is almost proportional to the way passed over. At the northeast point of Iceland, Langanæs, the temperature has sunk to about 1°, but even south of Langanæs we have unmistakable proofs that we have here a continuation of the eastern branch of the Irminger current, which thus turns around Langanæs towards the south along the east coast of Iceland and gives the waters over the coast shoal of East Iceland a physiognomy different from that of the surrounding sea, the distribution of temperature being another even if the temperature is not in any important degree higher than in the very East-Icelandic polar current.

We shall now finally emphasize that the conditions stated here will be quite disturbed in hard ice years. For when the masses of ice of the East-Greenlandic polar current reach the coast of the northwestern country they will — at least as to the surface — cut off the supply of the Atlantic water, and it is not improbable that they may totally force the warm water back in the Denmark Strait. In the first case the warm water will be covered by ice and cold ice-water, which it carries along with it towards the east, and so it cannot yield warmth to the air, in the latter case this whole territory will be filled with polar water. In both cases this source of warmth will have disappeared, and it is also a wellknown fact that the climate in North Iceland is much colder and rougher during the ice years than when the sea is free from ice.

Section II.

In this section which was taken in the days May 31. and June 2. we comprise St. 52 and 53 which are situated off the northwest land respectively in the mouth of the Isafjord and Ønundarfjord; this leads to a considerable bend of this section, but we have included these two stations because the current direction is parallel with the shore, and, consequently, the volumes of water which are at St. 51 near Cape North will some time before have been at St. 52 and St. 53. As mentioned in the introduction it was, unfortunately, impossible, on account of the unsteady weather, to take measurings in the depth between Cape North and Röde Huk, and so we miss the important statements: how far the proportionally warmer water in the western part of the section is stretching towards the east, as it has not yet reached the two eastern stations.

In the western part of the section (the Isafjordsdeep to Cape North) we find a considerably higher temperature than in the close of April; thus near Cape North (see St.s 12 and 51) the increase is about 2°5. At the station in the Isafjordsdeep the distribution of temperature, when the higher value is not considered, from a depth of 25 meters and downward resembles the conditions in April. Here we have a water layer with a very slightly increasing salinity, and the temperature is also growing in such a proportion that the specific gravity is constant, which thus means that this water layer has been subject to the influence of the convection. The commencing summer warmth has, however, warmed the upper surface layer a little, and as the salinity of the latter is also somewhat lower (34·92 ‰) on account of the mixture with shore water, this influence has now stopped, and the opposite condition begins to prevail, namely the warming from the surface.

This warming, however, is still only of slight importance; the temperature in the surface is thus only 0°08 higher than at the depth of 25 meters, and the warming cannot be supposed to have reached farther down, which is seen partly from the minimum of temperature found at this depth, partly from the fact that the specific gravity from this depth is nearly constant downward. When thus in the Isafjordsdeep we find volumes of water whose temperature is about 1°5 higher than that found in April we must, though the salinity is almost unaltered, from this higher temperature conclude that new volumes of water have been supplied which can only have come from the south.

From the Isafjordsdeep to Cape North the temperature decreases with about 0°7, and here we have again almost a constant temperature and salinity from the surface to the bottom, which as mentioned during the observations in April is certainly caused by the great speed of the tide currents. Besides Cape North, Langanæs and Staalbjærg Huk are well known in this respect, and that such an intense mixture of the whole water layer takes place is seen both from the hydrographic conditions, and also from the fact that Dr. SCHMIDT caught organisms, which are under standard conditions only found as bottom animals, in the surface off Staalbjærg Huk. The salinity is rather low here, and has decreased about 0·11 ‰ since April on account of the increased supply of fresh water occasioned by the commencing melting of the ice and snow masses of Iceland. That this factor is now playing a more considerable part than formerly is seen still more plainly at St. 53 (the mouth of Ønundarfjord), the salinity in the surface here being 33·64 ‰, at the bottom (25 meters) 34·31 ‰.

East of Cape North we find temperatures in the surface varying from 3°6 to 4°1; the salinity in the surface is also rather high, we even find a value of 34·97 ‰, which makes it probable that the bottom water in the Skagestrandsdeep is more than 35·00 ‰. From the surface temperature alone we cannot, however, form a judgment as to the temperature in the layer beneath, as we do not know how much the temperature of the air may have influenced the temperature of the surface. According to the meteorological observations at Grimsey in 1904, which have kindly been communicated to me by Mr. Afdelingschef JANTZEN, the earlier part of May was rather cool, the mean temperature from 1.—20. of May incl. being 1°2 (at 8 a. m.) but during the last third of the month the temperature was rather high, mean 5°4. This has also put its traces on the surface temperature, as the latter, which we shall see later, in the eastern part of the section has risen with 2°—3°, while this influence as already mentioned is very slight as to the warmer volumes of water in the western part of the section.

Off the Øfjord a sample was taken with a temperature of 2°00, and a salinity of 34·51 ‰, which is the lowest temperature observed on the whole route. Whether it arises from the warmer surface water being carried away by the wind (a hard gale was blowing) or we have an isolated area of surface water from higher shores here cannot be determined. That it cannot be of any large extent can, however, be seen from the two samples on both sides with a temperature of 4°—4°5, and at Grimsey a surface temperature of 4°5 was measured on the 28. and 30. of May, and on the 3. of June even 5°5. A like condition has indeed been observed at Grimsey on the 18. and 19. of May; for then a surface temperature of 2°0 was measured, though on the 7.—10. of May it was about 4°. Vigorous winds had, however, been blowing for several days from ESE, E, and then from ENE, which brought the temperature of the air down below the freezing point, and partly caused a cooling of the surface water, partly also carried surface water from colder regions to Grimsey, but we have unfortunately no observations from 11.—18. of May. On May 20. the wind shifted to SSE from whence it blew a few days, strength 6—8 Beaufort, and on the 21. the surface temperature was 3°5 and rose with 0°5 each of the following three days.

In the eastern part of the section we have a considerably lower temperature in the under layer than in the western. Thus at St. 50 it is about 1°3, and at St. 49 north of Langanæs it is only a little

more than 1°, and at the bottom it even sinks to 0°87. The surface water, however, is 2—3 degrees warmer but this is owing to a warming from the atmosphere and the sun which is seen from the temperature decreasing fast downward. The fall of temperature from 0 to 10 meters is thus respectively 1°21 and 0°71, from 0 to 25 meters (below this depth this warming is quite insignificant) it is 2°98 and 1°84.

The salinity in the lower layer (under 25 meters) is almost constant, 34·70—34·74 ‰, and of the same amount as that found in April at St. 15 south of Langanæs. In the warmer surface layer the salinity is considerably lower, at St. 50 it is even only 33·73 ‰ in the surface, which is owing to the coast water deficient of salt. This also shows that the higher surface temperature is really owing to warming from the sun and the atmosphere, as the fresh water during its stay in bays and fjords to which the supply chiefly takes place will be subject to a considerable warming because the temperature of the air in such fjords in summer is generally considerably higher than at sea.

The here stated facts may in brief be expressed in the following way: the surface temperature has risen with 2 degrees on an average since the measurings in April, but as to the eastern part this higher temperature is only found in a thin layer nearest the surface, and beneath we still find the lower temperature answering to the state in winter, that is, here we have still the cooled volumes of water in winter near North Iceland. In the western part of the section the rise of temperature, however, is of greater importance, as it has the same value to the very bottom, and this means here a supply of quite new volumes of water from the Denmark Strait. The salinity is almost unchanged excepting a lower value in the surface, arisen from a mixture with the coast water, which is now supplied in ampler quantities.

Sections III and IV.

We shall here with a few words mention the state in the northern part of the Denmark Strait as it plays a great part for North Iceland, for the volumes of water of Atlantic origin appearing near North Iceland are coming from the basin of the Denmark Strait. The base of these two sections, of which the first is going in a western direction from the mouth of the Arnarfjord till about 27° west longitude, the last from thence to the SSW, are the stations 54—60 which were taken in the days from the 17. to the 21. of June, that is only a few days later than the period in which the sections XII and XIII were taken in 1903[1]).

In the main features the conditions are also pretty equal in the sections III and XIII (1903). In 1903 the surface water had a very low temperature because Section XIII was situated quite near the edge of the volumes of ice of the East-Greenlandic polar current, while such conditions did not, of course, take place in 1904, as the ice was farther away. We refind the standard condition for the Atlantic water in summer: the maximum of temperature in the surface from whence the temperature is decreasing more or less quickly downwards. The surface temperature is on an average a little above 7° and decreases slowly and rather uniformly downward, from which will be seen that the warming from the atmosphere and the sun has not played a very great part, which is also seen from the fact that the temperature rises a little off from shore, which appears from a sinking of the 7° isotherm. An equal sinking of the 6° isotherm also takes place, and the latter seems to be almost parallel with the bottom, but else the temperature does not vary much and at the bottom it is only a little under 6°.

A condition deviating from this is, however, found at St. 54 in the mouth of the Arnarfjord, which we shall mention here, as it illustrates what we have said p. 7. The temperature is here more

[1]) Medd. fra Kom. for Havunders. Serie: Hydrografi. Bd. I. Nr. 4.

than 6° till a depth of 45 meters, at the depth of 47·5 meters it was still 5°89 but at the depth of 50 meters a temperature of 2°21 was measured. This fjord shows considerable depths — more than 100 meters — but outside the mouth is found a shoal with depths of about 40 meters, and in consequence hereof the cold bottom water arisen by convection in winter cannot get out as it is heavier than the volumes of water which invade in summer and compensate for the surface layer. This cold under layer which has arisen in winter in consequence of the influence of the convection will thus remain standing in summer, and only slowly change its temperature by conduction of heat from the above lying warmer water layers, and will possibly gradually and partly be carried along with these.

The salinity increases rather fast outward from the shore which appears in the section by the fact that the isohalines 34·75 ‰, 35·00 ‰, and 35·10 ‰ are going rather steeply from the surface and down to the bottom. The extension of the coast water, both its distance from shore and its extent in the depth, is rather considerable, but its influence is very slight or quite insensible towards the most western station (57) of the section. Here we find a salinity which is a little higher than in 1903. As the temperature only varies little, but the salinity much away from the shore the specific gravity curves will get an appearance somewhat equal to the isohalines, and as a consequence of the lower specific gravity near the shore the surface current away from the shore mentioned p. 8 will prevail. In accordance with this Dr. Schmidt showed pelagic fry of the cod spawning on the shore banks till more than 26° W longitude, that is to the same distance from shore as that in which we can show the coast water from the lower salinity in the surface water. This is, of course, not to be understood as if this extension had occured at this place, but it must be considered the result of the extension of coast water occurring along the whole western coast and perhaps partly along the south coast, as the surface current is on the whole parallel with the coast, however with the mentioned inclination to leave it. The course of the specific gravity curve 27·70 as well as the 6° isotherm indicate the opposite movement along the bottom, the reaction current towards the shore.

Section IV shows rather uniform volumes of water, and isohalines and isotherms are mostly horizontal. The surface temperature rises a little towards the southwestern part of the section where the higher value, more than 8°, rather has the character of having arisen by atmospherical influence to judge from the fast decrease downward. The 6° isotherm and the specific gravity curve 27·70, however, incline very much towards the SW. Even at a depth of 1200 meters we have water of about the same kind as south of Iceland at the same depth.

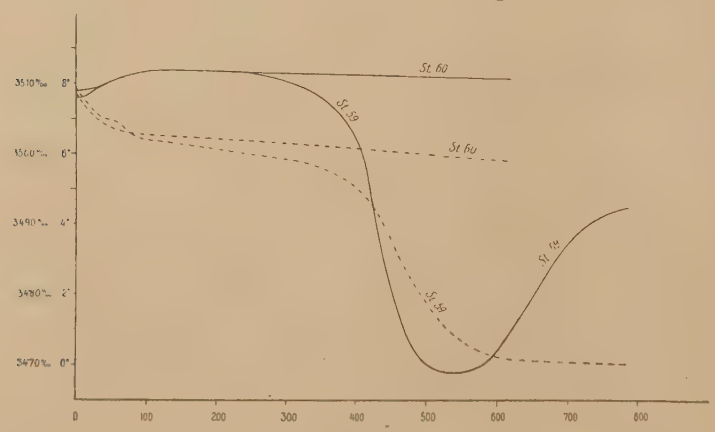


Fig. 4.

The conditions here are, however, far more complicated than appears from this section, as a station (59) was taken about 10 miles ESE from St. 60 which is highly different to the latter. Fig. 4 shows the distribution of temperature and salinity. We see that the salinity is quite the same till a depth of 200 m.; at a depth of 400 m. the difference is 0·09 ‰, but while at St. 60 the salinity keeps unchanged to the bottom, it decreases very fast at St. 59 and even sinks to 34·70 ‰ whence it grows again and assumes the value of 34·92 ‰ at the bottom (765 m.). Similar conditions prevail as to the temperature. At a depth of 400 m. the difference of temperature is about 1°, and while the temperature keeps rather constant downward at St. 60 it decreases

very fast at St. 59 and sinks to about 0° at the bottom. St. 60 thus shows prominent Atlantic water everywhere while at St. 59 at a depth of 600 m. we have prominent Arctic water, and finally we find at the bottom a water layer with the same qualities and, therefore, certainly of the same origin as the volumes of water which form the bottom layer in the Norwegian Sea, that is: arisen by a mixture of Arctic water and cooled Atlantic water.

According to the extensive measurings of the Ingolf expedition in the Denmark Strait the temperature in the whole basin even at the depth of 2000 m. is generally more than 3°, and, excepting a single station in the northwestern part, at least 1°4. Martin Knudsen supposes that in certain deeper parts there is almost standing water with a lower temperature. Such an explanation may very well be applied to the lower layer of the cold water occurring here, but it cannot probably be applied to the upper part of it (the Arctic water with the low salinity). We have certainly a somewhat lesser depth towards the west and probably also towards the south, but if the whole of this cold water layer should be protected against the warm water volumes streaming northwards, a ridge must be found between these two stations with depths of about 400 meters, which is rather improbable.

It is perhaps more probable that we have a local rotation here, but this explanation is also little satisfactory when we consider the enormous variation found at the short distance between the two stations.

Sections V and VI.

The stations included in the sections V and VI were taken in the days from the 20.—22. of July. The former stretches from Langanæs towards the west till Grimsey and is as to the most eastern stations situated near the coast. Section VI stretches from the Skjalfandibay across the Grimsey shoal towards the north till east of Mevenklint and reaches depths here of more than 800 meters, while none of the stations in Section V is situated outside the coast shoal and so do not show depths of 100 meters.

As the two sections are proximately right-angled on each other we must beforehand expect rather considerable differences, as the one must be supposed to go in the current direction and the other perpendicularly on this, and that is also affirmed by a closer consideration of their appearance. Section V, which is parallel with the shore, has namely an appearance which answers exactly to what must be expected of a section going in the moving direction of the water, that is proximately horizontal isotherms and isohalines but thus that the former rise a little towards the surface towards the east because the water volumes streaming towards the east are constantly followed by others with a higher temperature. The isohalines, however, sink a little downwards towards the east which is a natural consequence of the supply of fresher water, and, as the section is situated so near the shore, especially on account of the fresh water from shore. On account of this distribution of temperature and salinity the specific gravity curves will go almost horizontally and so the distribution of specific gravity will not cause differences in the hydrostatic pressure which may effect a somewhat strong current in the longitudinal direction of the section. As such a one, which we shall later point out, doubtlessly occurs, we must suppose that this movement takes place, because the volumes of water at other places have received a certain amount of motion, or in other words that the movement is kept up by the kinetic energy of the water particles.

If we compare Section V with the eastern part of the above mentioned Section II, the stations 49 and 50 of the latter lying very near the stations 71 and 72 in Section V, we perceive a rather considerable rise of temperature, not only in the surface, where it amounts to more than 5 degrees, but at the very bottom we have still a difference of 2°5. This rise of temperature cannot have taken place in consequence of a transmission of heat from the surface as it does not occur so fast [1]). We see, indeed,

[1]) H. Mohn: The North Ocean, its Depths, Temperature and Circulation. The Norwegian North-Atlantic Expedition 1876—1878. Bd. XVIII. p. 97. Further O. Nordgaard: Studier over Naturforholdene i vestlandske Fjorde. I. Hydrografi. Berg. Mus. Aarb. 1903. Nr. 8 p. 28.

that the transmission of heat from the surface at St. 75 has only prevailed until a depth of about 40 meters, the temperature falling fast until this depth while below we only find a slight variation in it. The explanation of this rise of the temperature in consequence of a transmission of heat — if on the whole it was possible — would, however, be refuted by the fact that the salinity at St. 72 in the nether layer is 0·10 ‰ greater than at the corresponding St. 50 and that we have thus really to do with quite new volumes of water. The only possible explanation will then be this that the water volumes which were found here towards the close of May have been displaced by other warmer volumes of water (with a somewhat higher salinity), which on account of the higher temperature can only have come from the west.

The surface temperature varies pretty much and rather irregularly and seems, in accordance with what has been said p. 15, the higher the greater the influence of the coast water is. The temperature in the under layer, however, grows as formerly from the east to the west; thus the bottom temperature grows with about the same value from St. 71 to St. 72 as from the latter station to St. 74, namely with about 0°8. The salinity of the surface which in April was about the same as in the under layer, but towards the close of May somewhat reduced by the fresh coast water has now sunk still more, so that it is rarely pretty much more than 34 ‰; at St. 72 it is even only 33·15 ‰; at Grimsey 33·91 ‰ was observed, from which we see that the coast water may prevail at a rather considerable distance from shore.

Section VI, however, must beforehand be supposed to go right-angled on the current direction and the appearance of the section fully affirms this supposition, as both the isotherms and the isohalines have a most irregular course. Here we must, however, except the 5° isotherm which goes rather horizontally, rising a little towards the north, but even this one shows a large curvature between the stations 75 and 76. In this connection we shall mention that the surface temperature is decreasing fast towards the north; at St. 73 in Skjalfandibay it is thus 10° 50 (already at a depth of 10 meters it is, however, sinking to 7° 12), at Grimsey it has sunk to 8° 40 and at the northmost station it assumes the value of 6° 11.

If, however, we consider the isotherms 4°, 2° and 1°, we find that they, lying very close together and near the surface in the northern part of the section, sink very steeply downwards towards the south, and all go down to the bottom on the northern slope of the Grimsey shoal, and by their form exclude the existence of a northgoing streaming, the 1° isotherm even shows a retrograde movement at St. 77. It may certainly be a possibility that we have to do here with almost standing volumes of water, and that the northern part of these were cooled by and partly mixed with the waters of the polar current, and that this was the cause of the above mentioned appearance of the isotherms, but as we know that the waters nearest the shore are continually renewed this possibility must be refuted.

We have said above that a northgoing current is incompatible with the appearance of the isotherms. For if we observe for instance that the 2° isotherm at St. 75 is found at a depth of fully 300 meters and at St. 77 at a depth of a little more than 50 meters we get the result that the mean speed of the waters whose temperature is more than 2 degrees during a northgoing movement must be about 6 times as great at St. 77 as at St. 75, a result which is quite illusory when we consider that the distance between the two stations is not upwards of 30 miles. Here we have indeed taken for granted that a loss of heat to the colder under-layer does not take place but as the distance between the two stations is so insignificant this will scarcely be of any great importance.

It is not, however, only the isotherms which point in this direction but the isohalines also give the section the character of one going perpendicularly on the current direction. Thus we see that the 35·00 ‰ isohaline appears as a closed curve, and that the 34·85 ‰ and 34·90 ‰ isohalines have a similar retrograde appearance as the 1° isotherm which cannot at all be united with a current in the

longitudinal direction of the section. We see that the 34·85 ‰ isohaline in the southermost part of the section is found at a depth of 75 meters and then rises a little towards the north and almost reaches the surface at St. 75. That this sinking of the isohaline towards shore is a consequence of the diluting influence of the coast water is without doubt. At the further end of the Skjalfandibay, where a couple of rivers abounding with water have their outlet, a salinity of 20 ‰ was thus observed in the surface, off Husevik it was 27·2 ‰, and at St. 73 31·62 ‰, but already at a depth of 10 meters it reached a value of more than 34 ‰. The salinity of the surface water increases towards the north, but only reaches its greatest value at St. 76, that is at a distance of 50 miles from the nearest point of Iceland. The lighter coast water which moves away from the shore as a surface current has thus prevailed until a distance of about 50 miles from shore.

We shall further mention an interesting condition in the distribution of the salinity. In the Skjalfandideep the salinity of the bottom water is more than 34·90 ‰ at depths of 100 meters or more while such a high value does not occur in the more shallow Station 74 near Grimsey, and it may be presumed that such a high salinity is not found on the whole on the shoal of water which stretches from this island towards the shore east of Øfjord. This more saliferous bottom water must then have passed north of Grimsey and then moved in about southern direction into the Skjalfandideep. As similar conditions must surely prevail as to the deeps, separated by such shoals, in which all the larger bays and fjords on North Iceland are continued, we see by looking at the chart that this bottom water must move a considerably farther distance than the straight line from the northwestern point to the place in question.

The northmost station in this section offers water of prominent Arctic origin: the temperature is sinking fast from the surface, and at a depth of 100 meters it is only a little above 0°, then again it rises downwards and decreases later on. The high temperature at 150 meters must surely be in close connection with the Irminger current, just as a not inconsiderable influence of these waters has prevailed which is seen both from the temperature and the salinity. In the bottom layer we find the characteristic feature for the whole Norwegian Sea: The nought isotherm at a depth of 500—600 meters and slightly decreasing temperature downwards; the salinity almost constant: 34·90—34·94 ‰.

The here mentioned stations 73—77 thus form a transverse section of the water volumes running north of Iceland of prominently Atlantic origin, and with these as a base we may then say that the eastern branch of the Irminger current at this time reaches in breadth from the coast to Mevenklint (about 60 miles) and in depth till about 300 meters. Furthermore we see that the warmest volumes of water as well in the surface as in the depth occur nearest the shore.

Section VII.

Three weeks after the researches mentioned last some observations were again made in the waters in question of which Section VII includes the stations 99—101 which were taken on the 12. and 13. of August a little south of Langanæs from the coast across the Bakkafjordsdeep in eastern direction.

That the conditions have altered a good deal during the past three weeks will, however, be seen by comparing St. 99 and St. 70 which was taken on the 20. of July 7 miles farther to the north but at a smaller depth. We see that the salinity has during that time been a good deal increased, this change, however, is of less importance compared with the change of temperature. From Fig. 5 we see that the difference in temperature is slight in the surface but is growing downwards, and is about 2 degrees at a depth of 50 meters. At the depth of 75 meters where transmission of heat from the surface is insignificant the rise is about 1°75. Since the 20. of July thus volumes of water with a higher

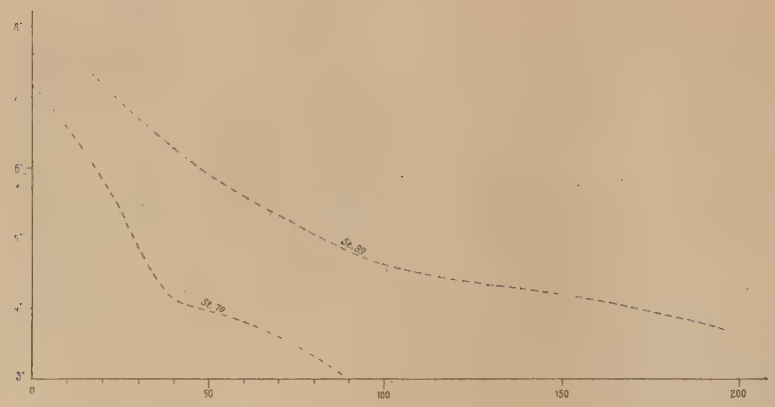


Fig. 5.

salinity and especially a considerably higher temperature, that is to say with more marked Atlantic qualities, have been streaming from North Iceland round Langanæs. That these volumes of water have come round Langanæs must be taken for granted as we find colder water farther to the south and east. Of course a similar change has occurred at the eastern part of the north coast which we shall see later (Section VIII).

Section VII bears on the whole a good deal of resemblance to Section VI. As in the latter we found the warmest water nearest the coast thus the same is seen here which appears from the fact that the 4° and 3° isotherms which in the eastern part of the section are lying close under the surface go rather steeply towards the bottom in the western part quite analogous with the corresponding isotherms in Section VI. The temperature at St. 99 is of about the same value as at the corresponding depths at St. 73 in the Skjalfandideep on July 21., which we see from the following table:

Depth (Meter)	Temperature St. 73	St. 99	Diff.
0	10·50	7·60	2·90
10	7·12	7·53	— 0·41
25	6·74	6·90	— 0·16
50	5·95	5·89	0·06
75	5·37	5·20	0·17
100	4·84	4·61	0·23
150	4·23	4·22	0·01
195 (185)	4·30	3·87	0·43

When the surface layer and that nearest the bottom are excepted the greatest difference of temperature at the same depth is 0°23, and at the depth of 150 meters the difference is even only 0·01. As we have formerly seen that the temperature at the same depth in July as well as earlier in the year varies considerably from west to east we can consequently say — granted that the water volumes streaming towards the east have not been perceptibly cooled on their way from the Skjalfandibay to Langanæs — that the volumes of water which we find at St. 99 on August 12. are the same as those found at St. 73 in the Skjalfandideep on July 21.

If we go towards the east from St. 99 the temperature sinks considerably until St. 100 but here it is still upwards of 2° to the very bottom. From St. 100 to St. 101 the fall of temperature is less, and here we find a powerful water layer of about 300 meters with a temperature from 2°5 to 2°. This powerful water layer may be considered a transition between the Irminger current and the surrounding Arctic water and by its high salinity — about 34·90 ‰ — it indicates that it has moved on the outer side of the warm water and that it has partly delivered its heat to the surrounding Arctic waters which it has gradually touched, while at the same time its salinity has been a little diminished by mixture with the Arctic water.

At St. 101 we observe a minimum of temperature at a depth of 75 meters which, how little marked it may be, is still sufficiently characteristic. From the surface till 50 meters the temperature

decreases from 7°90 to 2°46 and this fast decrease alone carries the thought to the surface water of the East-Icelandic polar current, and the fact that we find a lower temperature here than farther down shows that the upmost water layer cannot have participated in the movement north around Iceland as in this case it would be warmed by the warmer water from beneath. So we have really here surface water from the proper East-Icelandic polar current, the temperature as well as the salinity is, however, of course influenced by the Irminger water. When the two heterogeneous waters meet, the surface water, deficient of salt, from the polar current, as it is lighter than the warmer but salter Irminger water, will consequently continue to be surface water while the latter on account of the conditions of the specific gravity will get its place farther down but above the proper bottom layer. This condition is excellently illustrated in the section by the 34·90 ‰ isohaline. This goes pretty close to the surface in the midst of the section, towards the shore it is pressed downwards by the coast water, and in the outermost part of the section the same is effected by the surface water of the polar current.

At about the same place as St. 101 a station was taken (78) on July 23. which in the main features shows the same conditions, which are seen in Fig. 6. We see, however, that both the maximum and still more the minimum of salinity has gone downwards, that consequently both the surface layer deficient of salt and the salter water lying beneath it have increased in thickness, and that the maximum of temperature in the latter has also gone downwards, and that the temperature from this maximum decreases somewhat more slowly than before, while the maximum value has not been much increased. Thus we see that the change consists chiefly in a greater extension of the volumes of water of the same kind as those which in July were found at a depth of 100—150 meters: that the last volumes of water supplied have consequently quite the same character as the former, which we have seen is not the case in the heart of the Irminger current, and we conclude that we are near the edge of this current, in the transition layer to the polar water.

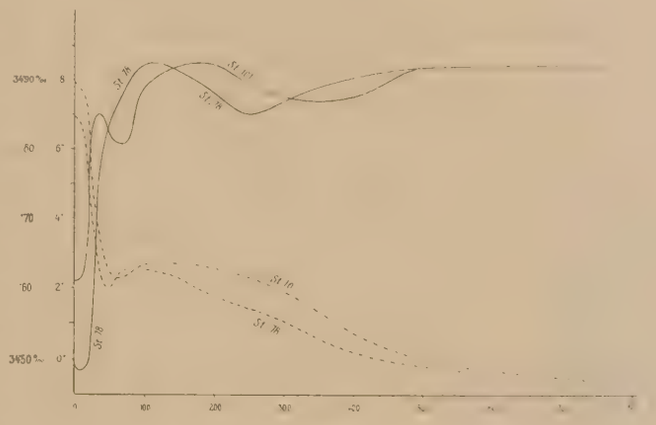


Fig. 6.

How far this transition layer is stretching towards the east is, of course, impossible to determine on the base of these observations, but from the extension which the Irminger current has here, we may, however, say that the eastern branch of the Irminger current plays a considerable part in the renewing of the proportionally warm layer — the intervening layer — which in the East-Icelandic polar current is found between the proper bottom layer and the ice water in the surface layer.

Section VIII.

As the last link in the chain of investigations in the waters in question here we shall mention Section VIII which stretches from the Isafjordsdeep till east of Langanæs. The east of Øfjord situated stations 101—104 were taken on the 14. and 15. of August, while the stations west of this fjord (105—108) were taken from the 22.—24. of August. The discontinuity in time thus occurs in the middle of the section and only amounts to a week.

If first we consider the eastern part of the section we observe a rather considerable rise of temperature since the measurings on the 20.—22. of July (Sections V and VI). In the Skjalfandideep

the 5° isotherm has been moved about 100 meters downwards, and only at the bottom the rise is of less importance but still clear (0°31). Towards Langanæs we find temperatures in the under layer which are between 1 and 2 degrees higher than at the end of July and the bottom temperature is even higher here than in the Skjalfandideep, however we cannot expect that the bottom temperature at Langanæs has reached its maximum value; for we have already seen (Section VI) that the bottom water from the deep moves round the coast shoals, and further we see that the temperature at the same depth is constantly decreasing from the west to the east, from which follows that even after this period warmer volumes of water will be carried to more eastern regions till the cooling from the atmosphere removes this supply of heat.

In connection with the rise of temperature the salinity also increases, and this is especially the case towards Langanæs where the rise of temperature was also the greatest; so we find a rather powerful waterlayer with a salinity of upwards of 34·90 ‰ in the Thistilfjord west of Langanæs.

We have here included St. 101, mentioned in the former section, and from the circumstance that the isotherms are rising fast towards this station we see that the volumes of water mentioned here do not continue their way to the east, as we must then at this station refind the volumes of water which in July we found near the eastern part of North Iceland, but we must suppose that they are turned towards the south by the southgoing East-Icelandic polar current along the east coast and keep closest to land, a condition which also clearly arose from Section VII.

After a week's stay at Øfjord the researches were continued towards the west and already at Siglenæs (St. 105) we meet with a most peculiar condition for this season finding a minimum of temperature of 7° in the surface from which the temperature rises with more than 1 degree to a depth of 25 meters. We cannot wonder that the salinity is very low, the station being very near the shore. Here we also find the conditions characteristic of such a station with a slight depth situated near the shore: a high and proportionally uniform temperature to the very bottom in connection with a low salinity. From here the surface temperature is decreasing fast towards the west, and at St. 106 in the Skagestrandsdeep we find still more prominent conditions as it has here sunk to 4°50, and the salinity is also very low, namely 32·18 ‰. Both the temperature and the salinity are rising downwards, but while the salinity is rising to the very bottom we reach a maximum of temperature of 6°30 already at a depth of 25 meters, when it sinks again to a minimum of 4°27 at a depth of 50 meters. Then the temperature is again rising though a little slower, and at a depth of 100 meters it reaches again a maximum of 6°12 whence it decreases slowly towards the bottom. The low surface temperature keeps towards the west until 21°30′ west longitude, where even 4°00 was observed, but here it springs suddenly, for about 4 miles farther towards the west a value of 9°20 was observed and this kept almost constant towards the west.

That this disturbance of the conditions is owing to the East-Greenlandic polar current is evident. A steamer passing Cape North towards the close of July thus states[1]) that ice was observed in northerly direction and during the first days of August drift-ice appeared in the Skagestrandsbay in such quantities that it impeded the navigation of sailing vessels, and even at the time when we were passing there was found a little scattered and much rotten drift-ice. Farther towards the east no ice has been observed near the coast and as these waters at this time were much frequented by the great, chiefly Norwegian, herring fishery fleet which often goes out in a considerable distance from shore, it may be considered certain that ice was not to be found here at all; furthermore we have no communication from Grimsey as to this.

The ice occurring near Cape North and in the Skagestrandsbay must rather be considered an insulated mass of ice which local winds have carried away from the proper East-Greenlandic polar

[1]) Naut. Met. Annual 1904.

current, and especially this can be said with certainty of that in the Skagestrandsbay. The masses of ice which are carried down over the warm water of the Irminger current will melt comparatively soon by which the Irminger water will be cooled and mixed with the ice-water. This cooling and diluting influence is seen to prevail until a depth of about 100 meters at St. 106 which makes it probable that together with the ice greater volumes of ice-water from the polar current have been supplied, as the melting of the ice alone can only with difficulty be supposed to have prevailed so far downward. Rather strange is the higher temperature at a depth of 25 meters. It is probable that the water in this depth was formerly surface water, and that then from the north or northwest a new supply of colder and very fresh ice-water took place which on account of its less specific gravity spreads across the volumes of water being here beforehand.

But what is of the greatest interest here is the considerable distance in which the ice and the ice-water from it is to be traced by the decrease in the surface temperature. On Aug. 15. the temperature in the surface water east of the Siglefjord was everywhere more than 8° and it did not show any regular variation, at the mouth of the Øfjord there was even a temperature of more than 9° and inside the Siglefjord 8°70. When we left the Øfjord on the 22. of August the temperature of the surface water was immediately strikingly low at St. 105 near Siglenæs, and this lower surface temperature is perhaps now found farther towards the east.

From the measurings of temperature at St. 105 alone it may be decided with certainty that we have an influence of the ice or the ice-water from it. The same would, of course, result from regular observations of the temperature of the surface water. From the observations of the surface temperature at the meteorological station on Grimsey[1]) it is thus seen that the surface temperature is rising until towards the close of July, when it is 9°—10°, then it begins to decrease slowly but quite regularly, and on the 20. of August it has sunk to 6°5; we thus get as a mean temperature for July 7°9 and for August 7°3, while the standard condition is that the temperature does not assume its maximum value till in August, and that this month shows the highest mean temperature. From this variation in the surface temperature it is also clearly seen that peculiar conditions are prevailing. That this decrease of the surface temperature is seen at Grimsey earlier than near the shore is a matter of course, as the supply of ice and of the colder water has taken place from the north side of the volumes of water streaming towards the east.

The circumstance that the warm water in the Irminger current is thus partly covered with ice and cold water puts its trace in the temperature of the air in a very conspicuous manner. While thus the mean value of the observations of the temperature of the air at 8 a. m. on Grimsey is 9°4 for July, it is 6°9 for August, while under standard conditions it is the same with the air as with the sea surface: that the maximum value only occurs in August and that the monthly mean temperature is the maximum in this month. —

The observations mentioned here in connection with the measurings of the temperature of the surface of the sea at the meteorological station on Grimsey thus seem to show that in the whole year 1904 (till the close of August) there has been a supply of volumes of water from the Denmark Strait to the sea north of Iceland to such an extent that they have been able to give all these waters their peculiar appearance. We saw, namely, that there were, late in April, even south of Langanæs (St. 15), volumes of water, which, though their temperature was not much higher than that which must be supposed to be found in the East-Icelandic polar current, by the vertical distribution of temperature clearly were indicated as a continuation of the Irminger current. From reasons which we shall later prove we must suppose that these volumes of water have been streaming past Northwest Iceland a few months

[1]) These observations have kindly been placed to my disposal by Mr. Afdelingschef JANTZEN; later they will be published in Meteorologisk Aarbog for 1904.

previously, and that such a supply has taken place since — and probably taken place continuously — is seen from the conditions found near North Iceland in April (Section I).

From the observations of the surface near Grimsey it is seen that the temperature of the surface in the beginning of January 1904 was 3°, a temperature which indicates water of partly Atlantic origin, as the surface water of the polar current, which in summer is warmed by the sun and the atmosphere, not, however to any great depth, can be supposed to keep so high a temperature so late in winter. The surface temperatures measured in February and March seem also to be a little higher than what might be expected of the surface water of the polar current[1]). In the table below we find the mean temperatures of the surface water near Grimsey for the first 8 months of 1904:

January	February	March	April	May	June	July	August
1°4	0°4	0°4	1°0	3°3	6°7	7°9	7°3

I must here remark that the observations in the winter months are generally very scarce, and so I have by interpolation from the observations formed mean values for periods of 5 days and from these again formed the mean value for months to avoid that a casual heaping up of the observations in the beginning or the close of the month should get too predominating an influence on the mean temperature of the month.

As we thus in January find water of partly Atlantic origin in the waters north of Iceland, and we know that such a supply takes place at most a few months later, it lies near to suppose that such a streaming of water from the northern part of the Denmark Strait to the sea north of Iceland takes place continuously all the year round at all events when the ice conditions permit it.

The cause of this streaming must, as we have formerly mentioned, be sought in the kinetic energy of these volumes of water, as in the Denmark Strait they move towards the north along the west coast of Iceland and will continue this movement if they meet no impediment on their way. Such an impediment will for a part of the warm water volumes of the Denmark Strait streaming towards the north be found in the ice-carrying East-Greenlandic polar current which generally is found west of Northwest Iceland at about 66° n lat., and according to M. Knudsen[2]) the greater part will be carried back through the Denmark Strait on the outer side of the polar current while — as was the case in 1904, possibly on account of good ice conditions — another part will run on to North Iceland. This part — the eastern branch of the Irminger current — will on account of the rotation of the earth be bent towards the east, when the coast no longer prevents this bending, a condition which we find everywhere on the northern hemisphere for a current going towards the north, while conversely a current running towards the south will be bent towards the west. A concurrent cause of this bending of the eastern branch of the Irminger current being so sudden is probably owing to a pressure from the waters of the East-Greenlandic polar current.

Here we touch the next question, namely the direction and speed of the current. From former researches[3]) we know that these warm volumes of water off the western part of the north coast keep nearest to the latter, and it will be most reasonable to suppose that the current direction will continue being parallel with the coast, a condition which appears clearly from Section VII, as we also here find the warmest volumes of water nearest the shore. Admiral Wandel[4]), however, has on the base of his comprehensive and careful observations as commander of a mailsteamer advanced the opinion that the eastgoing warm current off the Melrakkasletten leaves the coast in northern direction. This is, however, easily understood for the duty on board has generally only permitted such observations as

[1]) Compare the Norwegian measurings in May 1904. Bulletin des résultats etc. Mai 1904.
[2]) Martin Knudsen: The Danish Ingolf Expedition.
[3]) Martin Knudsen: l. c.
[4]) C. F. Wandel: Bemærkninger til Besejlingen af Islands Kyster. Københ. 1879.

could be made during the sailing, and observations of the surface alone may in these waters easily get fallacious if they are not supported by measurings in the deep; we have thus seen that the surface temperature at the eastern part of North Iceland in winter is only a little higher than that of the polar water. Nor will the sets of the current mentioned by Admiral WANDEL exclude a continued eastern movement past the Melrakkasletten; for the form of the coast makes it probable that along the west side of the peninsula the current is running in a northern direction past the Røde Huk and that on the east side it presses into the Thistilfjord.

In Section XIV of the Ingolfexpedition (north and a little west of Langanæs) we also find the warmest volumes of water at the station (123) nearest the coast but on account of the low salinity here the hydrographer of the expedition mentioned advances a rather complicated current system in consequence of which the surface water of the polar current should move across the Irminger current down to the north coast of Iceland and here partly sink downwards and press the Irminger current away from the coast. The waters of the latter should then appear farther northwards in the section and some rather high values for the salinity have certainly been observed, but the corresponding temperatures do not deviate conspicuously from the general one of the polar current. Under these circumstances it may well be supposed that the proportionally warm under layer at the southermost station (Temp. 2°—3°5) arises from the Irminger current, and that the low salinity arises partly from the coast water partly from mixture with polar water. The value for the salinity at a depth of 50 fathoms being lower than at a depth of 30 fathoms seems indeed to indicate that the waterbottle has not been quite tight but has permitted a partly mixture with the surface water deficient of salt so that the low salinity may possibly partly be explained by this. At Ingolf's St. 126 a salinity of 34·36 ‰ at a depth of 552 m. is thus indicated; the later Norwegian as well as Danish measurings in the Norwegian Sea give a rather constant value for the salinity below a depth of 500 meters, namely 34·90—34·95 ‰, and so it is probable that the above mentioned low value is owing to some error in the observation.

As we must thus suppose that the Irminger current is continued along North Iceland to Langanæs it lies near to suppose that partly by the rotation of the earth and partly by the East-Icelandic polar current running southwards it is bent towards the south along the east coast, and from Section VII it appears clearly that such a bent towards the south has taken place and that we constantly have the heart of the current nearest the shore. At Langanæs the Atlantic character of the current is not by far so prominent as at the western part of North Iceland and on its way towards the south the latter will by degrees be still further effaced. How far to the south it may be proved depends, of course, on the quantity of heat amassed in these waters. Thus we have formerly mentioned[1]) that in the close of May 1903 on the coast shoal north-east of Seydisfjord conditions were found which indicated a continuation of the Irminger current and we shall later get an opportunity of mentioning that in August 1904 near the east coast of Iceland at 65° n lat. an under layer was found which surely had been carried there from North Iceland.

The speed of the water volumes mentioned here will probably partly be dependent on the speed of the current in the surrounding waters, and will thus probably be less at the western part of the north coast than at the eastern part of the latter and at the east coast, as we have an opposite movement of the East-Greenlandic polar current while the movement of the East-Icelandic polar current is going in the same direction. The whole waterlayer of the Irminger current seems mostly to move as an entire whole, still the speed at the bottom is probably a little diminished on account of the friction.

On the base of some current bottles which were thrown out north of Iceland and landed again on the north coast, Captain RYDER[2]) states the speed in the surface to be 6—7 miles a day, the mean

[1]) Hydrography of the Waters etc.

[2]) C. RYDER: Some Investigations Relating to the Ocean Currents in the Sea between Norway, Scotland and Greenland. Naut.-Met. Annual 1901.

speed of the speediest bottle being 6·2 miles a day. Such a bottle will generally give a lower limit for the speed of the current, but when the bottle, as was here the case, has only been a short time (here 8 days) on its passage the local direction of the wind will easily get such an influence on the speed of the surface water that it can be reckoned a higher value than the standard one. At the time when the here mentioned bottle was at sea west of Grimsey whereupon it landed, the direction of the wind on Grimsey [1]) shifted somewhat frequently and only the last few days the wind became predominantly west. The abovementioned value, fully 6 miles a day, must thus be supposed to be rather uninfluenced by the local conditions of wind, while on the other hand this value is so high that there is no reason to suppose that the bottle has been lying several days on shore before it was found.

On the base of the hydrographic observations in hand, the speed of the current in the surface is not to be determined because the conditions are so variable: in winter the surface water is cooled on its way to the east, in summer it is warmed up and is also subject to a great dilution. At such depths where these two factors are of slight or of no importance — in this case depths of above 50 meters — we may, however, determine the speed of the current, provided that 1) the current courses are horizontal, 2) that the physical and chemical qualities of the water volumes are not altered on their way. If thus we fancy a station taken in the Irminger current at the western part of North Iceland we know that the waters move towards the east and when after a certain time at a station near the eastern north coast we find the same values of temperature and salinity at the same depths (except the surface layer) the water volumes from the first station will thus have reached here, and we may then find the mean speed of these water volumes as the distance between the two stations divided by the time elapsed. We have, indeed, several times pointed out that a rise of temperature in the under layer will only take place in consequence of a supply of water from more western regions.

Neither of the abovementioned two suppositions will be strictly accomplished. The current courses must partly accommodate themselves to the form of the sea bottom, and the warm volumes of water coming from the west will, when we except the surface layer influenced by the sun and the atmosphere, always be subject to a cooling, for instance by streaming over colder bottom water and partly by mixture with the colder volumes of water being there beforehand. On account of this cooling the mentioned determination of the current speed at a depth to which the warming from the surface cannot reach will always give a lower limit for it.

As an instance we may take the stations 52 in the Isafjordsdeep (June 2.), 73 in the Skjalfandi-deep (July 21.), and 55 off the Dyrafjord (June 18.), as the latter is so near the shore that the water volumes here must be supposed to continue their way to North Iceland:

Depth (Meter)	Temperature St. 52	St. 73	St. 55
0	4°25	10°50	6°89
10	4°24	7°12	5°88
25	4°17	6°74	5°90
50	4°19	5°95	5°85
75	4°25	5°37	(80 m.) 5°84
100	4°34	4°84	
125	—	4°39	
142	4°37	—	
150		4°23	
195		4°30	

From this we see that the temperature at a depth of 50 meters is about the same at St. 55 and St. 73 while in the nethermost layer at the stations 52 and 73 it is of about the same value. So we may

[1]) Met. Aarbog 1899. Part II.

with the abovementioned reservation say that the speed of the current at a depth of 50 meters is $\frac{198}{33} = 6{\cdot}0$ miles in 24 hours from the northwest land to the Skjalfandideep, while at depths of about 125 meters it is $\frac{152}{49} = 3{\cdot}1$ miles in 24 hours.

From the comparison stated p. 20 between St. 73 and St. 99 will be seen that the speed of the layer from 50—150 meters from the Skjalfandideep past Langanæs is about $\frac{97}{22} = 4{\cdot}4$ miles in 24 hours while it is a little less at the bottom. On account of the shorter distance between the stations the percentile uncertainty here is greater than in the former case while the uncertainty in consequence of the insufficiency of the suppositions is independent of the distances.

As particular mixture phenomena seem to occur off prominent points where the tide current is running with great speed, it is possible that warming from the surface may have prevailed until depths of 50 meters even if it would be excluded farther out at sea; for this reason the above indicated value of the current speed at a depth of 50 meters, 6·0 miles a day, may be a little too great, while at greater depths and especially towards the bottom it must be supposed to have been found smaller than it really is on account of the formerly mentioned cooling and mixture which, though rather slightly, has taken place which is seen from the somewhat lower salinity towards the east. The lower speed in the bottom layer arises further partly from the fact that the bottom water moves round the coast shoal (see Section VI) and so accomplishes a proportionally longer way than the surface water; for we must remember that the above found values for the speed were the composants of it in the direction west-east. This composant must in the eastern branch of the Irminger current according to what is stated above be supposed to be about 4 miles a day at a depth of 150 meters, about 6 miles a day at a depth of 50 meters, and in the surface according to Captain Ryder 6—7 miles a day (the mean speed from Cape North to Langanæs).

Concluding Remarks.

The Atlantic volumes of water which by the Irminger current are carried to the sea north of Iceland are of great importance in more than one respect. We have thus mentioned that these warmer volumes of water in winter yield a considerable quantity of heat to the atmosphere, and consequently we must suppose that the temperature in winter at North Iceland depends on the extent of the eastern branch of the Irminger current. This appears quite evidently from the following table which contains the mean temperatures of the air at Grimsey for 1902[1]), when with shorter or longer interruptions ice occurred near North Iceland from January 8. till the middle of June, and for 1904, when there was no ice until in the month of August when some drift-ice appeared at the western part of North Iceland:

	January	February	March	April	May	June	July	August
1902	— 6°8	— 6°9	— 5°8	— 2°3	0°1	3°6	5°2	5°9
1904	— 1°8	— 1°1	— 1°5	— 0°4	3°1	7°5	9°3	7°1

This streaming also seems to be of importance to the fishery. Thus Johs. Schmidt mentions[2]) that the cod spawning near South Iceland are gradually passing off towards the north along the west coast and further along the north coast. While thus the cod fishery in the south of the country is undertaken in March—April it commences in May in the northwest of the country, and the farther we get towards the east along the north coast the later it commences. Thus it seems that the spawned cod are going with the current to the west, north, and east parts of Iceland, and that they do not appear in

[1]) Met. Aarb. 1902.

[2]) Johs. Schmidt: Fiskeriundersøgelser ved Island og Færøerne i 1903.

larger quantities until the temperature of the water reaches a certain value. The great herring fishery which towards the close of summer is also undertaken near North Iceland is probably also dependent of the state in the Irminger current which, however, pro tem. is an open question.

Not only the cod spawning near South Iceland but also the pelagic fry of them are carried with the current along the west and north coasts; the current probably also plays a part by thus distributing the fry over a many times larger area whereby it gains more favourable conditions of life.

By observation of the time when this pelagic cod fry appears at different places we may also get an approximate value for the speed of the current. As this fry did not appear near the north of Iceland in the beginning of June, and was only found in greater numbers off the northwest land on the 17th of June, while on the 21st of July it was found in greater numbers in the Skjalfandideep, and there were only found a few specimens farther towards the east[1]), we see that also in this way we get the value of the mean speed of the surface layer, found on the preceding page, namely about 6 miles in 24 hours.

Under Section VIII we have mentioned how great an influence the drift-ice occurring in the Skagestrandsbay was exercising on the surface water of the Irminger current and especially on the temperature of it, and to how great an extent this influence could be proved with certainty by mere measuring of temperature.

It is a wellknown fact that the coasts of North Iceland are often blocked up by large quantities of drift-ice which may even lay itself as land-ice. Among the population of fishers the most fantastic reports are told of how the ice may suddenly come drifting to the shore without anybody beforehand having any idea of its existence at sea, a circumstance which may, however, partly be explained by the mist which generally accompanies it. It will easily be imagined how great a misfortune it is for the population of the place who partly gain their living by fishing, that all intercourse and the most important trade is stopped in this way. There are instances of a very severe want of provision by the fjords blocked up by the ice in hard ice years.

When the ice approaches the shore which generally is first reached by Cape North the cold ice-water, deficient of salt, which is always found outside the ice edge spreads over the warmer but still heavier water volumes of the Irminger current, and thus by a more or less sudden diminution of the surface temperature indicates that the ice is approaching. This colder water will move towards the east on the surface of the Irminger water, and farther towards the east it may by the mere variation of the surface temperature be determined when the ice conditions are threatening.

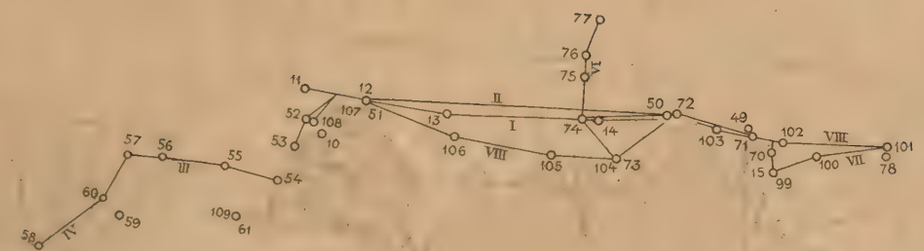
As the projected telegraph cable to Iceland will probably very soon be followed by a wire round the whole island it would certainly be most desirable if some stations of observation were established in North Iceland, one near Cape North, the other farther to the east near Skagetaa or Siglenæs. When beforehand it was generally known — even if only a couple of days — that there was danger of a blocking up by ice, much would already be gained, and there is no doubt that a man who had the necessary knowledge of the standard conditions and the standard variation in them would gain excellent results by such an ice-warning-service.

[1]) These informations have kindly been communicated to me by the ichthyologist of the expedition, Dr. Johs. Schmidt.

Important Corrections.

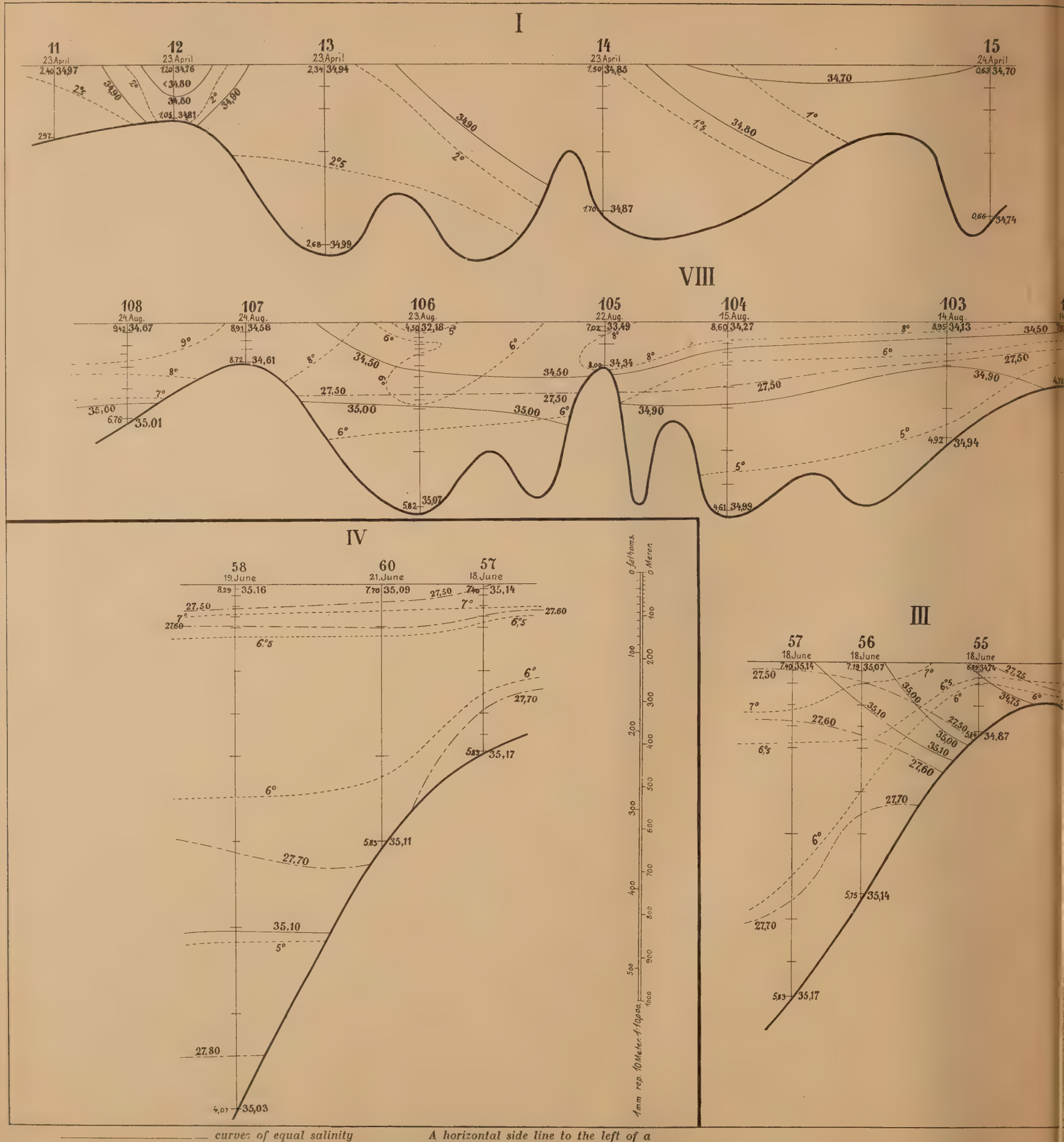
Page 8, line 9, after: on the southeastern coast of Iceland read: in the summer 1904.
— 9, 14 lines from foot, for: 1·60 read: 1·68.
— 18, line 1, for: St. 75 read: St. 72.
— 24, line 6, for: can be supposed read: cannot be supposed.
— 24, 5 lines from foot, for: Section VII read: Section VI.
— 26, 11 lines from foot, for: 5°88 read: 6°88.

Medd. fra Kom. for Havunders. Serie Hydrografi Bd. I Nr. 7 Pl. I



ISLAND

100 Kilometer



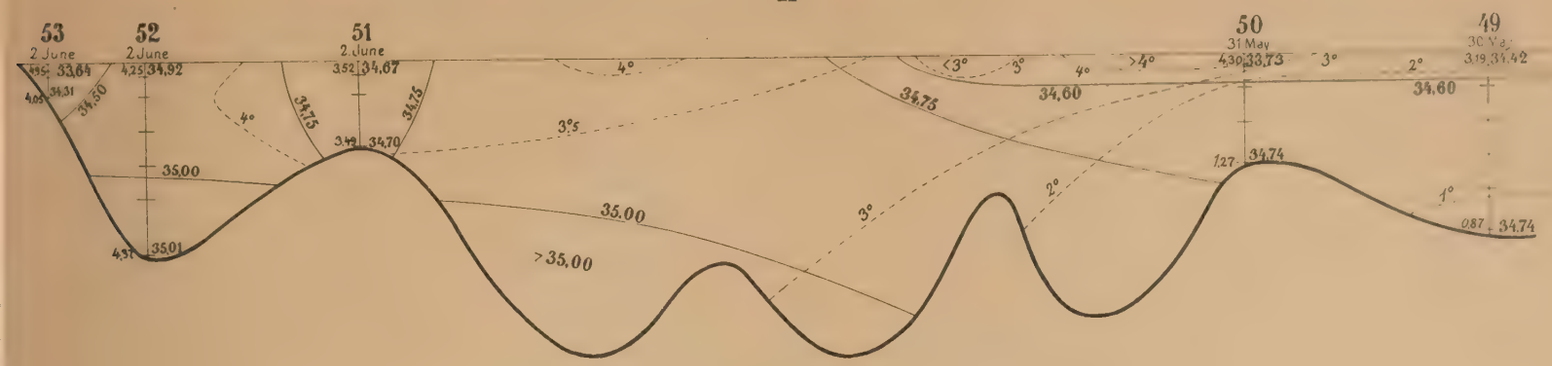
curves of equal salinity

curves of equal temperature

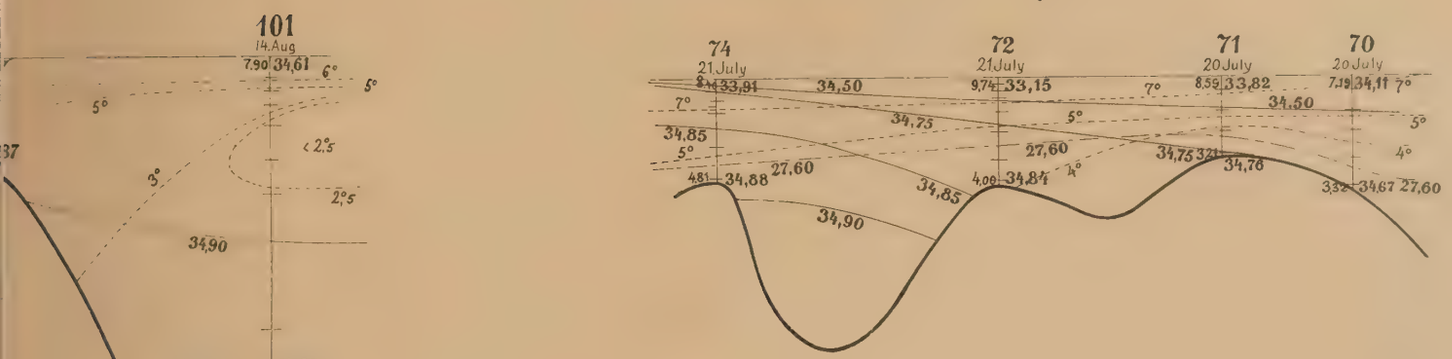
curves of equal σ_t

A horizontal side line to the left of a vertical line at a station represents an observation of temperature; one to the right an observation of salinity.

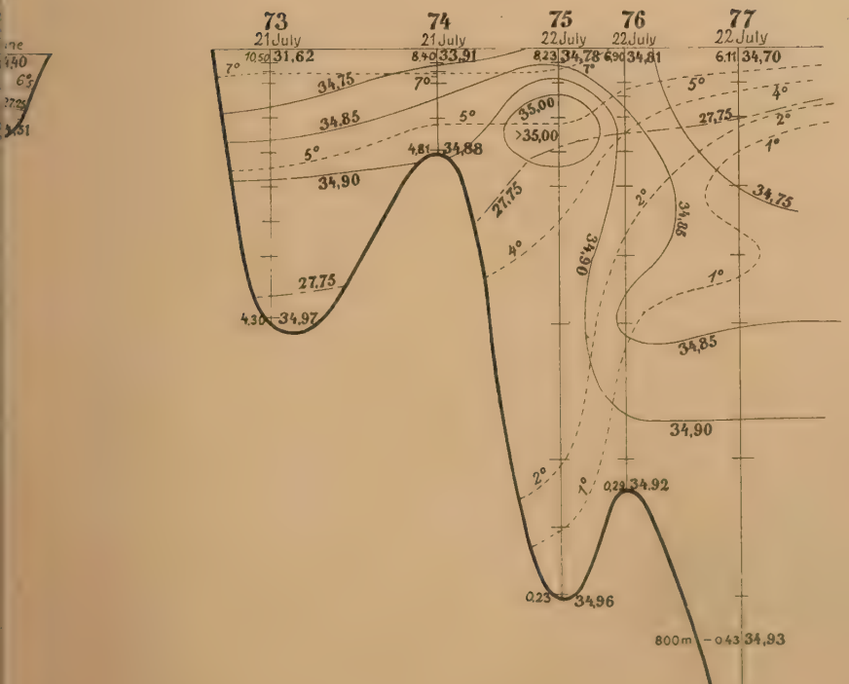
II


53
2 June
52
2 June
51
2 June
50
31 May
49
30 May
35,00
>35,00
34,60
34,74

V

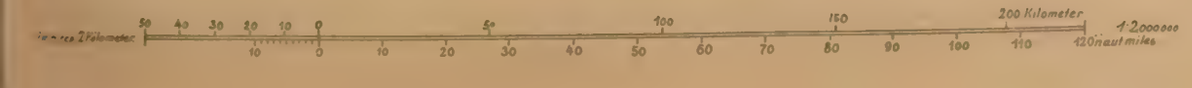

101
14.Aug
74
21.July
72
21.July
71
20.July
70
20.July
34,50
34,75
34,85
34,90
27,60
34,88
34,84
34,78
34,67

VI


73
21.July
74
21.July
75
22.July
76
22.July
77
22.July
34,75
34,85
34,90
27,75
35,00
>35,00
34,88
34,96
34,92
34,93

VII

99
12.Aug.
100
13.Aug.
101
14.Aug
34,80
34,90
>34,90
27,90
34,92


200 Kilometer
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120 naut miles

MEDDELELSER FRA KOMMISSIONEN FOR HAVUNDERSØGELSER
SERIE: HYDROGRAFI · BIND I · NR. 8 · 1905

DIE LÖSLICHKEIT VON SAUERSTOFF IM MEERWASSER

DURCH WINKLERS TITRIERMETHODE BESTIMMT

VON

J. P. JACOBSEN

KØBENHAVN
I KOMMISSION HOS C. A. REITZEL
BIANCO LUNOS BOGTRYKKERI
1905

Die Löslichkeit von Sauerstoff im Meerwasser durch Winklers Titriermethode bestimmt

Bei den vierteljährlichen Untersuchungen in den dänischen Gewässern sind an einzelnen festen Stationen einige Bestimmungen von Sauerstoffgehalt des Meerwassers bewerkstelligt worden, gleichzeitig mit Planktoneinsammlungen und den gewöhnlichen Temperatur- und Salzgehaltbestimmungen. Die Bestimmungen sind alle nach einer bestimmten Methode ausgeführt, welche von Magister N. Bjerrum ausgearbeitet und in den Mitteilungen der Kommission beschrieben worden ist.[1])

Da es von Interesse sein wird, den Unterschied zwischen der Menge von Sauerstoff zu bestimmen, welche das Meerwasser enthält, und der Sauerstoffmenge, die es bei der vorhandenen Temperatur enthalten könnte, habe ich zufolge einer Aufforderung von Docent Martin Knudsen einige Bestimmungen des Absorptionskoeffizienten von Sauerstoff im Meerwasser unternommen, indem bei den Bestimmungen hauptsächlich Rücksicht darauf genommen wurde, dass sie nach derselben Methode geschahen, wie die gewöhnlichen Bestimmungen.

Eventuelle systematische Abweichungen von den Werten des Sauerstoffgehalts bei anderen Methoden sind somit annehmlich von keinem Einfluss auf die oben genannte Differenz.

Die zu den Versuchen benutzten Wasserproben sind von dem dänischen Postdampfschiff „Laura" auf der Route Kopenhagen—Island eingesammelt worden, und zwar teils im offenen Atlantischen Ozean, teils in der Nordsee und zum Teil im Kattegatt. Das Wasser wurde an Bord durch kalkfreien Filter auf Sechsliterflaschen filtriert, in welchen es aufbewahrt wurde. In untenstehender Tabelle sind sowohl Zeit und Ort des Einsammeln der Wasserproben, wie auch deren Salzgehalt angegeben. In den zwei letzten Kolumnen sind die Nummern der Proben, an denen später Messungen vorgenommen wurden, und welche teilweise durch Verdünnung mit destilliertem Wasser aus den ursprünglichen zubereitet sind nebst ihrem ungefähren Salzgehalt angeführt.

Tabelle 1.

Datum	Ort	Salz ‰	Benutzt zu	Salz ‰
1904 3. November	Lappens Feuerschiff	14·38	1 a	7
— 27. Oktober..	61°24′ N.Br. 12°20′ W.L.	35·17	1 b	7
— 1. November	56° 6′ — 1° 4′ —	34·78	2	14
— 3. —	Lappens Feuerschiff	14·38	3	14
— 1. —	56° 6′ N.Br. 1° 4′ W.L.	34·78	4	21
— 3. —	Trindelen	24·99	5	25
— 26. Oktober..	63° 5′ N.Br 18°45′ W.L.	35·12	6	28
— 2. November	55°57′ — 0°52′ O.L.	35·01	7 a	35
— 27. Oktober..	61°24′ — 12°20′ W.L.	35·17	7 b	35

[1]) Meddelelser fra Kommissionen for Havundersøgelser, Serie: Hydrografi. Bind I Nr. 5. København 1904.

Zu der Absorption im Wasser wurde atmosphärische Luft angewendet, welche ausserhalb des Gebäudes genommen und durch Röhren in den Absorptionsapparat geleitet wurde; sie wurde von Kohlensäure befreit, indem sie durch Kalihydrat geleitet wurde.

Der Absorptionsapparat, welcher in Fig. 1 abgebildet ist, besteht aus einer grossen Flasche, welche ca. 15 Liter fasst, und welche, indem sie in einer Walze in liegender Stellung angebracht ist, von einem Motor mit passender Schnelligkeit um eine horizontale Achse gedreht werden kann. Die Walze ist mit zwei kreisrunden Holzstücken als Endflächen versehen, diese sind durch 6 Seitenleisten verbunden, und durch Querleisten ist dafür gesorgt, dass die Flasche in der Mitte der Walze fest sitzt. Auf den Endflächen sind Zapfen befestigt, welche als Umdrehungsachse dienen; der eine dieser Zapfen ist hohl; durch diesen geht ein Thermometer in die Flasche. Das Thermometer ist mittels Pfropfen im Zapfen und Flaschenhals befestigt. Durch den Pfropfen in der Flasche gehen zwei Glasröhren, die eine bis auf den Boden der Flasche, die andere bis unmittelbar unter den Propfen; sie münden beide in das entsprechende Endstück der Walze und sind mit kleinen Stücken Kautschukschlauch versehen, welche durch Glaspfropfen geschlossen werden können. Der Behälter des Thermometers befindet sich gleich unter dem Pfropfen der Flasche.

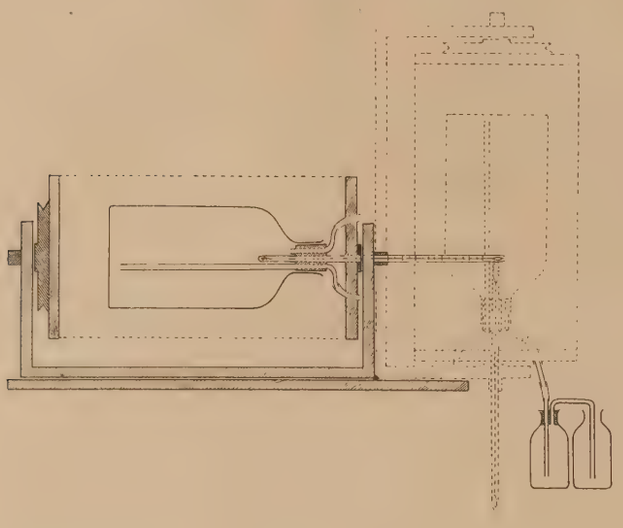

Fig. 1.

Wenn z. B. 1 Liter Wasser in die Flasche gebracht wird und die Walze mit dieser in Bewegung gesetzt wird, wird unter der Bewegung die ganze inwendige Seite der Flasche mit einer Wasserschicht belegt, welche immerfort erneuert wird. Die ausgedehnte Flüssigkeitsoberfläche, die dadurch entsteht, bewirkt, dass die Absorption der in der Flasche vorhandenen Luft rasch vor sich geht. Die Luft in der Flasche wurde bei jeder Versuchsreihe durch Luft von aussen erneuert.

Da es von Wichtigkeit ist, dass die Temperatur von Wasser und Luft ziemlich konstant bleibt, wurde zunächst dafür gesorgt, dass die Temperatur des Zimmers ungefähr dieselbe war wie diejenige, bei der die Absorption gemessen werden sollte, und damit etwaige und unabwendbare Veränderungen der Lufttemperatur des Zimmers nur ganz geringen Einfluss auf die Temperatur des Wassers und der Luft in der Flasche haben sollten, war diese mit einer dicken Schicht Wolle umgeben. Um diese war eine gebogene Zinkplatte gelegt, welche also die Oberfläche der Walze bildete.

Es ist leicht zu verstehen, dass man mit Hilfe eines Trichters im Stande war, das Wasser in die Flasche zu bringen in der Stellung, wie die Figur sie uns zeigt. Um das Wasser abzuzapfen und gleichzeitig die Temperatur des Wassers zu messen, war es notwendig, dass die Flasche senkrecht mit dem Hals nach unten gestellt wurde; dies wurde dadurch ermöglicht, dass das Gestell, an welchem die Walze angebracht war, durch eine Viertelumdrehung in die auf der Figur punktierte Lage gebracht werden konnte. Das Thermometer wurde auf diese Weise in umgekehrter Stellung abgelesen; damit das Quecksilber nicht herablaufe, war der Raum oberhalb desselben mit Wasserstoff gefüllt.

Das Verfahren bei der Abzapfung einer Wasserprobe und deren weiterer Behandlung war genau so, wie es in der oben citierten Abhandlung beschrieben ist. Es ist zu erwähnen, dass der davon herrührende Fehler, dass das Wasser beim Füllen der kleinen Flaschen Sauerstoff von der Atmosphäre aufnehme, hier verschwindend sein muss, da das Wasser immer gesättigt ist und die Luft beinahe dieselbe Temperatur hat wie das Wasser.

Die Luft, die während des Abzapfens in die Flasche geführt werden musste, wurde von aussen

hineingeleitet. Das Füllen einer Flasche mit Wasser für eine Bestimmung sieht man in Fig. 1 ganz unten rechts; das Wasser in der anderen Flasche wurde zur Chlorbestimmung benutzt. Nach dem Zusatz der Reagenzien wurde die Flasche geschüttelt und in der Regel auf 1 bis 2 Tage hingestellt, bis das Titrieren stattfand.

Die Natron-Jodkaliumlösung (36 Gramm Na OH + 10 Gramm K J in 100 ccm. Lösung) wurde durch den Zusatz von Stärkelösung, nachdem sie sauer gemacht worden war, nicht blau gefärbt, ebensowenig wie die Manganochloridlösung (40 Gramm $MnCl_2 . 4H_2O$ in 100 ccm. Lösung) nach dem Zusatz von Stärkelösung und Jodkalium.

Das Titrieren der ausgeschiedenen Jodmenge wurde mit einer Burette ausgeführt, die zum Chlortitrieren eingerichtet war und Teilungen in 2 ccm. und unteren Zulauf hatte. Die Stärke der Thiosulfatlösung war ungefähr 2 Gramm Salz pro Liter. Bevor sie in Anwendung gebracht wurde, hatte sie längere Zeit unbenutzt gestanden. Ihre Stärke wurde unter den Messungen zu wiederholten Malen bestimmt, teils durch Abwiegen von saurem jodsaurem Kali, teils durch Abwiegen von Jod, das unmittelbar vorher sublimiert worden war. Die Lösung von saurem jodsaurem Kali enthielt ungefähr 1 Gramm in 1 Liter, die Jodlösung ungefähr 2 Gramm Jod in 1 Liter mit 4 Gramm Jodkalium. Zum Abmessen der Flüssigkeitsmengen, welche titriert wurden, wurde eine Knudsen'sche Pipette mit oben doppelt durchbohrtem Hahne angewendet.

Eine Vergleichung der verschiedenen Bestimmungen sieht man aus untenstehender Tabelle. Die Sauerstoffmenge ist in Cubiccentimetern bei 0° und 760 mm. angegeben.

Tabelle 2.

	Sauerstoffmenge, welche 2 ccm. Thiosulfatlösung entspricht.				
	Erste Lösung		Zweite Lösung		
	3. Dezemb.	16. Februar	1. März	3. März	23. März
1. Lösung von KHJ_2O_6 zubereitet am 3. Dez. 1904	0·0801	0·0748			
2. — - — — - 3. —	0·0802	0·0748			
3. — - — — - 16. Febr. 1905		0·0747	0·0877		0·0859
4. — - — — - 16. — —		0·0747	0·0877	0·0875	0·0860
5. — - J + KJ — - 1. März —			0·0883		
6. — - — — - 2. — —				0·0875	
7. — - KHJ_2O_6 — - 18. — —					0·0858

Ausser diesen Vergleichungen wurde immerfort an einer der Lösungen von saurem jodsaurem Kali titriert, wenn eine Reihe Bestimmungen vorgenommen wurde. Auf nebenstehender Fig. 2 ist die Zeit als Abscisse und der Logarithmus der Menge Sauerstoff, welche 2 ccm. Thiosulfat entspricht, als Ordinate abgesetzt; man sieht, wie die Lösung sich mit der Zeit verändert.

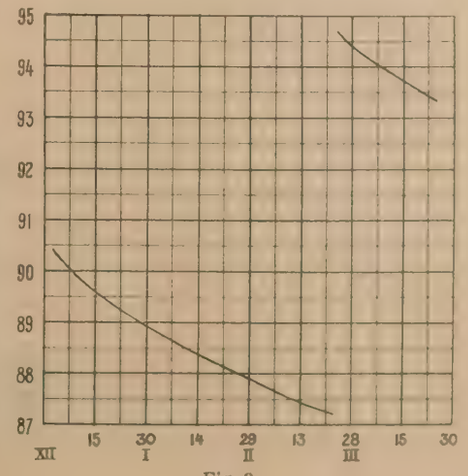

Fig. 2.

Um darüber klar zu werden, wie schnell die Absorption vor sich geht, wurden einige vorläufige Messungen mit destilliertem Wasser gemacht. Hier kann eine Reihe bei ungefähr 20° angeführt werden (siehe Tabelle 3). Ungefähr 4 Liter destilliertes Wasser, das durch Kochen teilweise von Luft befreit war, wurde um 1 Uhr 45 Min. in den Apparat geleitet, und die Walze wurde gleich darauf in Bewegung versetzt.

Die angeführten Temperaturen beziehen sich sowohl hier als weiterhin auf das Wasserstoffthermometer, ebenso wie die Sauerstoffmengenangaben in ccm. bei 0° und 760 mm. Luftdruck angegeben sind und die Sauerstoffmenge bezeichnen, welche von 1 Liter Wasser bei der angegebenen Temperatur absorbiert

Tabelle 3.

Wasser eingebracht 1^{45}	Temperatur	Sauerstoffmenge	Sauerstoffmenge (nach Winkler)	Differenz
Probe 1^{50}	20·63	5·10	6·43	÷ 1·33
— 2^{05}	20·68	6·19	6·43	÷ 0·24
— 2^{25}	20·73	6·31	6·42	÷ 0·11
— 2^{35}	20·75	6·28	6·42	÷ 0·14
— 2^{50}	20·78	6·23	6·41	÷ 0·18
— 3^{05}	20·81	6·20	6·41	÷ 0·21
— 3^{20}	20·85			
— 3^{35}	20·85	6·21	6·41	÷ 0·20
— 3^{50}	20·87	6·20	6·40	÷ 0·20
— 4^{05}	20·90	6·27	6·40	÷ 0·13
— 4^{20}	20·93	6·31	6·40	÷ 0·09
— 4^{35}	21·08	6·29	6·38	÷ 0·09
— 4^{50}	21·26	6·16	6·36	÷ 0·20
— 5^{05}	21·45	6·24	6·34	÷ 0·10

wird, wenn der Druck der atmosphärischen Luft allein ohne Wasserdampf 760 mm. ist. Es wird bei diesen und allen folgenden Versuchen angenommen, dass der prozentige Sauerstoffgehalt der Atmosphäre innerhalb der Abweichungen, welche die Observationsfehler verursachen, konstant ist. Der Barometerstand bezieht sich auf 0° und 45° Breite.

In der Tabelle sind zugleich die Werte der Sauerstoffmenge angeführt, welche den observierten Temperaturen, nach Winkler's [1]) Zahlen berechnet, entsprechen; man sieht, dass zwischen den beiden Reihen von Werten eine systematische Abweichung besteht, und da diese sich bei späteren Messungen stets wiederholt, und es nicht gelungen ist, eine Erklärung dafür zu finden, scheint es natürlich, das Hauptgewicht auf die früher genannte Differenz zwischen der vorgefundenen Sauerstoffmenge und der zur Sättigung notwendigen zu legen.

Man sieht, dass die Absorption trotz der grossen Menge Wasser ziemlich schnell vor sich geht, sodass sie jedenfalls nach $^3/_4$ Stunden als vollständig betrachtet werden kann. Die letzten Messungen von 4^{20} an bis 5^{05} sind bei einer Umdrehungsgeschwindigkeit der Walze von 120 Umdrehungen in der Minute unternommen worden, während bei den ersten ca. 50—60 Umdrehungen in der Minute geschahen, welche Umdrehungsgeschwindigkeit die gewöhnliche war. Man sieht, dass bei den drei letzten Observationen wegen der Reibung im Wasser eine ziemlich schnelle Temperatursteigerung stattgefunden hat. Möglicherweise kann das der Grund dafür sein, dass die Differenz bei den letzten drei Messungen geringer ist, als bei den übrigen, da das Wasser bei der steigenden Temperatur nicht all den Sauerstoff abgegeben hat, den es abgeben sollte. Der Unterschied ist jedoch so klein, dass man annehmen darf, dass die Umdrehungsgeschwindigkeit keinen Einfluss auf die Sättigungsgrenze hat.

Wenn von den beiden ersten Messungen abgesehen wird, bei denen das Wasser nicht mit Sauerstoff gesättigt war, ist die Durchschnittszahl der Differenzen 0·15, was also die systematische Abweichung zwischen den hier gefundenen Werten und Winklers Zahlen ist.

Möglicherweise könnte die Art und Weise selbst, in welcher die Sättigung der Flüssigkeit mit Sauerstoff ausgeführt wird, auf die Menge Sauerstoff, die absorbiert wird, Einfluss haben, sodass man bei einer anderen Methode eine andere Sättigungsgrenze erhalten würde; es wäre ja denkbar, dass, wenn Wasser kräftig mit Luft zusammengeschüttelt wird, dann die ganz kleinen Luftblasen, die sich so schnell bilden, wegen des grossen Kapillardruckes, welcher sich in der Blase findet, in der Flüssigkeit absorbiert

[1]) L. W. Winkler: Die Löslichkeit des Sauerstoffes in Wasser. Berichte der deutschen chemischen Gesellschaft 1889 S 1764.

werden könnten. Es muss angenommen werden, dass die absorbierte Luftmenge dann grösser sein würde, als bei dem Versuche mit der Walze.

Um dies zu probieren, wurde eine Flasche von ungefähr 2 Litern in einer Holzkiste angebracht. Um die Flasche wurde Wolle gepackt. Die Flasche war mit einer Ablaufrinne versehen, so dass die Füllung der kleinen Flasche zum Titrieren auf gewöhnliche Art vor sich ging. Es wurde dafür gesorgt, dass die Temperatur im Zimmer ungefähr dieselbe war, wie die in der Flasche.

Die Resultate sind in der untenstehenden Tabelle angeführt. Um ferner zu probieren, ob der Luftgehalt des Wassers, bevor der Sättigungsprozess begann, irgend einen Einfluss auf die Grenze haben sollte, bei welcher die Sättigung als vollständig gilt, wurde ein Versuch mit Wasser gemacht, das im Anfang entweder von Luft übersättigt oder nicht gesättigt war. Siehe die Tabelle.

Beim Zusatz der Reagenzien wird ja etwas von dem mit Luft gesättigten Wasser ablaufen, während andererseits beim Zusatz von Salzsäure luftfreies Wasser auslaufen wird; es wird schwierig sein, diese Fehler zu beseitigen, und da es bei den gewöhnlichen Bestimmungen nicht geschieht, wurde es auch hier unterlassen. Ferner kann nicht vermieden werden, dass mit der Pipette etwas Luft in die Flasche geführt wird, sodass auch dadurch Fehler entstehen können.

Um einen Begriff davon zu bekommen, welchen Einfluss der Zusatz der Reagenzien hatte, wurden einzelnen Wasserproben 4 mal so grosse Mengen wie anderen zugesetzt, von denen angenommen werden muss, dass sie denselben Sauerstoffgehalt haben, wie die ersteren, da sie unmittelbar nacheinander genommen und im Uebrigen auf dieselbe Art behandelt wurden.

In der Tabelle ist die hinzugesetzte Menge angegeben, sodass z. B. 4 bedeutet, dass 4 Pipetten à 1 ccm. mit Natronhydrat-Jodkalium und 4 Pipetten à $^1/_2$ ccm. mit Manganochlorid in gewöhnlicher Weise auf den Boden der Flasche geleitet wurden, und dass der Bodensatz später dadurch aufgelöst wurde, dass 4 Pipetten à 2 ccm. mit starker Salzsäure in gewöhnlicher Weise auf den Boden hinuntergeleitet wurden.

Hier folgen die verschiedenen Resultate zu einer Tabelle vereinigt.

Tabelle 4.

Datum	Reagenzienmenge	Verwendeter Apparat	Sättigungszustand	Angewandte Zeit zur Absorption	Temperatur	Barometerstand ÷ Dampfdruck	Observierte Sauerstoffmenge	Sauerstoffmenge auf 760 mm Luftdruck zurückgef.	Sauerstoffmenge nach Winkler	Differenz
März 11.	1	Umdrehungsapp.		60 min.	12·76	735·1	7·22	7·46	7·50	÷ 0·04
— -	4	—		60 —	—	—	7·15	7·38	7·50	÷ 0·12
— -	4	—		60 —	—	—	7·15	7·38	7·50	÷ 0·12
— 12.	1	Schüttelapparat		20 —	16·8	738·5	6·35	6·52	6·91	÷ 0·39
— -	1	—		30 —	17·05	738·2	6·52	6·71	6·87	÷ 0·16
— -	1	—		40 —	17·4	737·8	6·39	6·58	6·83	÷ 0·25
— 13.	1	Umdrehungsapp.	Uebersättigt	45 —	16·69	739·2	6·62	6·80	6·92	÷ 0·12
— -	4	—	—	45 —	—	—	6·63	6·81	6·92	÷ 0·11
— -	1	—	—	60 —	16·74	739·0	6·64	6·83	6·92	÷ 0·09
— -	4	—	—	60 —	—	—	6·58	6·77	6·92	÷ 0·15
— -	1	—	—	80 —	16·79	738·8	6·66	6·85	6·91	÷ 0·06
— -	4	—	—	80 —	—	—	6·50	6·68	6·91	÷ 0·23
— 16.	1	Schüttelapparat	—	20 —	19·6	736·0	6·26	6·46	6·55	÷ 0·09
— -	1	—	—	30 —	19·7	—	6·29	6·49	6·54	÷ 0·05
— -	1	—	—	40 —	19·9	—	6·22	6·42	6·52	÷ 0·10
— -	1	—	Nicht gesättigt	20 —	21·4	735·0	6·01	6·20	6·34	÷ 0·14
— -	1	—	—	30 —	21·45	—	6·02	6·22	6·34	÷ 0·12
— -	1	—	—	40 —	21·45	—	6·00	6·20	6·34	÷ 0·14

In der vorletzten Kolumne der Tabelle sind die den observierten Temperaturen entsprechenden Zahlen der Sauerstoffmenge nach Winkler und in der letzten Kolumne die Differenz zwischen diesen und den gefundenen angeführt. Diese Differenzen haben alle dasselbe Vorzeichen, und keiner von den variierenden Umständen kann als Ursache dieser systematischen Abweichungen angenommen werden. Man sieht aus den Zahlen, dass es ohne Einfluss ist, ob die Absorption im Schüttel- oder im Umdrehungsapparat vor sich geht. Dagegen scheint der Zusatz von 4 mal so viel Reagenzienmenge die Sauerstoffmenge ein wenig zu verringern, jedoch kaum mehr als um 1%. Es könnte auch scheinen, dass die Sauerstoffmenge geringer ist, wenn das Wasser im Anfange nicht gesättigt war; andererseits aber scheint Sättigung stets stattgefunden zu haben, und die Temperaturvariationen sind keineswegs so gross, dass die Absorption des Sauerstoffs ihnen nicht sollte gleichkommen können.

Zur Kontrolle der Messungen von Sauerstoff im Wasser wurde eine Bestimmung von Sauerstoff in der atmosphärischen Luft in ähnlicher Weise versucht, wie die Bestimmung für das Wasser.

Der angewandte Apparat ist in der nebenstehenden Figur dargestellt. Der Behälter *A* fasst 358·1 ccm, die Röhre *B* unten fasst ca. 3 ccm. und ist mit Teilungsstrichen für ganze Kubikcentimeter versehen. Der untere Hahn hat schräge parallele Durchbohrungen, sodass die Röhre *B* teils mit dem Behälter *A*, teils mit der Röhre *C* in Verbindung gesetzt werden kann.

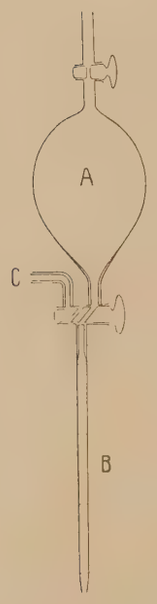

Fig. 3.

Der Gang des Versuches war folgender: Der Behälter wurde mit Luft von aussen gefüllt; einige Kubikcentimeter Wasser wurden in den Behälter getan, sodass die Luft mit Feuchtigkeit gesättigt war. Der Behälter wurde im Wasserbad angebracht und ausgepumpt, bis der Druck z. B. 4—5 cm. Quecksilber war. Der Druck wurde so genau als möglich durch ein Manometer bestimmt, das mittels eines Kathetometer abgelesen wurde; zugleich wurde die Temperatur bestimmt.

Danach wurde luftfreies destilliertes Wasser in den Behälter gebracht, nachdem die Röhren *B* und *C* erst damit durch den doppelt durchbohrten Hahn ausgespült waren. Der Behälter wurde ungefähr zur Hälfte gefüllt; darauf wurden die gewöhnlichen Reagenzien hinzugesetzt zur Absorption von Sauerstoff in demselben Verhältnisse wie bei den Wasserproben und in einer Menge, welche ungefähr in demselben Verhältnisse zu der Sauerstoffmenge stand, wie die Reagenzienmenge bei den Wasserproben zur Sauerstoffmenge in denselben.

Nach einem viertelstündigen Umschütteln wurde der Sauerstoff als absorbiert betrachtet und Salzsäure wurde hinzugesetzt, 2 ccm. starke Salzsäure für 1 ccm. Natronlösung. Die Reagenzienmenge wurde mit der Röhre *B* abgemessen und durch doppelt durchbohrten Hahn bequem hineingebracht.

Wenn der Niederschlag aufgelöst war, was sehr schnell ging, da er vermittels des Umschüttelns so fein verteilt war, wurde die Flüssigkeit in ein Glas getan und auf gewöhnliche Weise titriert.

Wie grosse Genauigkeit bei einem solchen Versuch erreicht werden kann, lässt sich ja nicht so leicht ermessen. Das Auskochen des destillierten Wassers nahm ungefähr eine Stunde in Anspruch. Von dem Kolben, in dem das Auskochen stattfand, führte eine lange (1 Meter) enge Glasröhre zu einem Verdichter hin. Das Auspumpen geschah mit einer Wasserluftpumpe, welche den Druck auf ungefähr 2 cm. hielt. Somit ist anzunehmen, dass der Partialdruck vom Sauerstoff im Kolben selbst 0 sein muss, und dass der Sauerstoff also ausgekocht wird.

Das Wasser wurde dann in den Behälter geleitet, ohne dass es mit der Luft in Berührung kam. Siehe Figur 4.

Es wurden einige Versuche mit Wasserstoff statt atmosphärischer Luft im Behälter gemacht; das Titrieren ergab so wenig Sauerstoffmenge (ca. 0·02 ccm.), dass in Hinblick darauf, dass die Reagenzien etwas Sauerstoff enthalten, die Sauerstoffmenge in dem ausgekochten Wasser 0 gewesen sein muss.

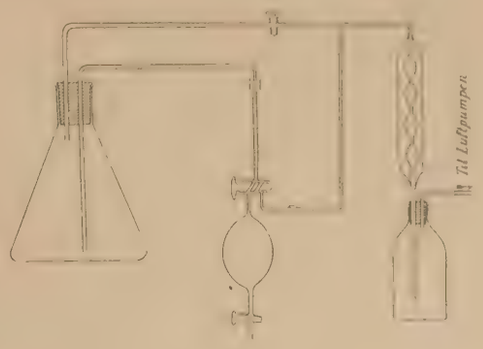

Fig. 4.

Ausser den eigentlichen Observationsfehlern, die sich namentlich bei dem Messen des Druckes geltend machen, kann annehmlich ein Fehler, und zwar ein systematischer Fehler dadurch entstehen, dass das ausgeschiedene Jod von der Hahnschmiere absorbiert wird. Als Hahnschmiere wurde „geschmolzener Kautschukschlauch" verwendet. Durch einen vorläufigen Versuch wurde festgestellt, wie viel Jod diese Schmiere unter ähnlichen Verhältnissen absorbiere, wie denjenigen, unter welchen eine solche Absorption im Apparate vor sich gehen musste; nur musste diese Jodmenge bei dem vorläufigen Versuch grösser, wahrscheinlich viel grösser sein als bei dem eigentlichen Versuche; es wurde eine Absorption von Jod nachgewiesen, die 0·06 ccm Sauerstoff entsprach, was bei den unten genannten Versuchen ungefähr 1 % entsprechen würde, aber voraussichtlich ist der Fehler, der dabei entstanden ist, viel kleiner.

Hier folgt eine Uebersicht über die gefundenen Werte.

Tabelle 5.

Volumen der Luft.	Luftdruck	Temperat.	Sauerstoff berechnet	Sauerstoff gefunden	Differenz
ccm.	mm.		ccm.	ccm.	ccm.
355·1	36·8	10·1	3·45	3·16	0·29
357·8	58·0	8·4	5·51	5·19	0·32
357·7	54·8	14·1	5·10	4·71	0·39
357·8	60·7	10·0	5·73	5·54	0·19
357·6	62·1	9·5	5·87	5·54	0·33

Die unter „Sauerstoff berechnet" angeführten Werte sind aus dem Volumen der Luft dem Druck und der Temperatur der Luft berechnet unter der Voraussetzung, dass die Sauerstoffmenge 20·8 % der ganzen Luftmenge ausmachte; die unter „Sauerstoff gefunden" angeführten Werte sind durch Titrierung bestimmt; man sieht, dass diese ungefähr um 6 % niedriger sind als die ersteren.

Es könnte danach scheinen, als ob der entstandene Niederschlag nicht im Stande wäre, allen vorhandenen Sauerstoff zu absorbieren; ist dies der Fall, so wird ganz natürlich die Differenz des Luftraumes wegen bei diesem Versuch grösser als bei den Versuchen mit den Wasserproben.

Wie aus Tabelle 1 Seite 3 hervorgeht, sind die zu den eigentlichen Versuchen benutzten Wasserproben teils die direkt geschöpften, teils durch Verdünnung von Proben mit höherm Salzgehalt erzeugte Wasserproben. Ausserdem sind immerfort Messungen von destilliertem Wasser angestellt worden, sodass folgende Stufen im Salzgehalt entstehen: 0, 7, 14, 21, 28 und 35 ‰.

Die Messungen der absorbierten Sauerstoffmenge wurden für diese 6 Salzgehalte auf einmal bei derselben Temperatur ausgeführt, nämlich bei 0, 5, 10, 15, 20 und 25°, indem, wie früher erwähnt, dafür gesorgt wurde, dass die Temperatur der Luft im Zimmer ungefähr dieselbe war, wie die des Wassers in der Flasche; dies liess sich jedoch bei der Messung bei 0° nicht ganz bewerkstelligen; diese Temperatur wurde ziemlich annähernd dadurch erreicht, dass geschabtes Eis unter die Wolle gemengt wurde. Aus Rücksicht auf die Füllung der Flaschen zum Titrieren, wurde die Temperatur des Zimmers doch bei dieser Messung so niedrig wie möglich (2 à 3°) gehalten.

Der Versuch mit jeder einzelnen Wasserprobe dauerte eine Stunde. Bevor das Wasser (ungefähr 700 ccm.) in die Flasche geleitet wurde, die sich in der Walze befand, wurde dafür gesorgt, dass es ungefähr die Temperatur hatte, bei welcher die Messung angestellt werden sollte — dieselbe Temperatur, welche die Flasche und annähernd auch die Luft hatten. Nach dem Füllen fand 20 Minuten lang die Umdrehung der Walze statt, dann wurde eine Temperaturmessung des Wassers ausgeführt; nach weiteren 20 Minuten fand wieder eine Temperaturmessung statt, und dieses Mal wurde gleichzeitig eine Probe zur Bestimmung der Sauerstoffmenge genommen; nach Verlauf von 15 Minuten wurde dieses wiederholt. In der Regel ergab sich eine Steigerung der Temperatur um 1 à 2 Zehntelgrade; es ist anzunehmen, dass sie von dem kräftigen Umrühren herrührt.

Bei jeder Messung wurde der Stand des Barometers beobachtet. Nennt man die Sauerstoffmenge, welche sich durch die Titrierung als von 1 Liter Wasser absorbiert ergab, A, indem der Sauerstoff in ccm. bei 0° und 760 mm. Druck gemessen wird, und den reduzierten Barometerstand B, sowie den Druck der gesättigten Dämpfe, der mit hinreichender Genauigkeit bei Meerwasser derselbe ist, wie bei destilliertem Wasser, bei der Observationstemperatur f, so findet man

$$M = A \frac{760}{B-f}.$$

M ist somit die Menge Sauerstoff, welche bei der vorhandenen Temperatur und dem vorhandenen Salzgehalt unter einem Druck von atmosphärischer Luft von 760 mm. ohne Wasserdampf von 1 Liter Wasser absorbiert werden könnte.

In der nachfolgenden Tabelle 6 sind die Werte von M und die dazu gehörende Temperatur angeführt. Mit Hilfe der Bestimmungen der absorbierten Sauerstoffmenge nach Winkler (l. c.) und für Ozeanwasser nach Dittmar[1]) ist auf die Werte interpoliert, welche M bei genau 0, 5, 10, 15, 20 und 25° haben würde.

Schliesslich sind die Differenzen zwischen den Resultaten der 2 Reihen aufgeführt; da sich bei diesen Differenzen keine systematische Reihenfolge zeigt, muss angenommen werden, dass die Sättigung des Wassers mit Luft eine vollständige war. Die Werte der letzten Reihe können daher als Wiederholungen derer der ersten Reihe betrachtet werden, und die Differenzen zwischen ihnen dienen also zu einer Bestimmung des mittleren Fehlers der einzelnen Beobachtung, indem deren Quadrat gleich der Summe der Quadrate der Differenzen durch ihre doppelte Anzahl dividiert gesetzt werden kann.

Bei der Berechnung des mittleren Fehlers sind die beiden Observationen weggelassen, welche in eine Paranthese gesetzt sind, da angenommen werden muss, dass diese mit besonderen Versuchsfehlern behaftet sind. Das Quadrat des mittleren Fehlers, auf oben genannte Weise berechnet, wird 0·70, also der mittlere Fehler ungefähr 0·08 für eine einzelne Observation.

Um die Ausgleichungsrechnung zu erleichtern, wurde aus den Observationspaaren Durchschnittszahlen gebildet, die wie einzelne Observationen behandelt wurden. Die beiden in eine Paranthese gesetzten Observationen wurden auch hier weggelassen, sowie auch die mit * bezeichneten, indem es vielleicht denkbar wäre, dass diese Proben von naturgemäss vorkommendem Meerwasser mit niedrigem Salzgehalt im Verhältnis zu den durch Verdünnung von Ozeanwasser hergestellten Wasserproben eine Sonderstellung einnehmen könnten.

Da der Chlorgehalt der Proben, an welchen die Observationen angestellt wurden, in der Nähe von 0, 4, 8, 12, 16 und 20 gelegen ist, wurde eine Reduktion der oben erwähnten Durchschnittszahlen der Sauerstoffmenge auf diese Werte des Chlorgehalts mit Hilfe von Winklers und Dittmars Zahlen ausgeführt; dadurch wurde erreicht, dass die Ausgleichungsrechnung bedeutend vereinfacht wurde. Es zeigte sich, dass die Sauerstoffmenge M mit genügender Genauigkeit durch folgende Formel ausgedrückt wird:

$$M = 10{\cdot}062 - 0{\cdot}2822\,t + 0{\cdot}006144\,t^2 - 0{\cdot}000061\,t^3 - 0{\cdot}1073\,Cl + 0{\cdot}003586\,t\,Cl - 0{\cdot}0000550\,t^2\,Cl.$$

t ist die Temperatur, Cl die Chlormenge, ausgedrückt in pro mille. Mit Hilfe dieser Formel ist die Tabelle 7 berechnet.

[1]) Report on the scientific Results of the Voyage of H. M. S. Challenger: Physics and Chemistry Vol. I, p. 224.

Tabelle 6.

Probe-zeichen	Chlor-gehalt	Temperatur		Sauerstoffmenge M		Sauerstoffmenge reduziert auf 0°, 5°, 10° u. s. w.		Differenz	observ.—berechnet	
		I	II	I	II	I	II		I	II
D.W.	0·00	0·23	0·23	10·04	10·05	10·11	10·12	÷ 0.01	0·04	0·05
1 a	3·87	0·29	0·27	9·55	8·96	9·63	(9·04)		÷ 0·01	(÷ 0·61)
2	7·78	0·29	0·27	9·19	8·93	9·26	9·00	0·26	0·04	÷ 0·23
4	11·61	0·28		8·80		8·87			0 03	
6	15·70	0·21	0·22	8·32	8·33	8·37	8·38	÷ 0·01	÷ 0·01	0 00
7 a	19·29	0·22	0·23	7·98	7·88	8·03	7·93	0·10	0·04	÷ 0·06
7 b	19·46	0·22	0·24	7·97	7·92	8·02	7·97	0·05	0·05	0·00
D.W.	0·00	5·33	5·41	8·79	8·71	8·87	8·80	0·07	0·06	0·00
1 a	4·07	5.52	5·57	8·44	8·33	8·56	8·46	0·10	0·12	0·02
2	8·06	5·33	5·43	7·91	8·00	7·98	8·09	÷ 0·11	÷ 0·09	0·02
3 *	8·15	5·30	5·38	8·00	7·96	8·07	8·04	0·03	0·00	÷ 0·03
4	11·90	5·31	5·35	7·71	7·67	7·77	7·74	0·03	0·05	0·02
6	15·24	5·23	5·31	7·33	7·37	7·37	7·43	÷ 0·06	÷ 0·05	0·01
7 a	19·89	5·42	5·45	6·96	6·98	7·03	7·06	÷ 0·03	0·04	0·07
D.W.	0·00	5·34	5·44	8·85	8·74	8·93	8·84	0·09	0·12	0·04
1 a	3·94	5·42	5·52	8·06	8·35	8·16	8·47	÷ 0·31	÷ 0·29	0·02
2	7·79	5·48	5·52	7·37	7·92	(7·48)	8·03		(÷ 0·63)	÷ 0·07
3 *	7·96	5·18	5·24	8·01	7·99	8·05	8·06	÷ 0·01	÷ 0·03	÷ 0·03
4	11·63	5·13	5·15	7·73	7·62	7·76	7·65	0·11	0·01	÷ 0·09
5 *	13·78	4·87	4·94	7·57	7·53	7·55	7·52	0·03	0·01	÷ 0·02
6	15·53	4·91	4·94	7·39	7·40	7·37	7·39	÷ 0·02	÷ 0·02	0·00
7 a	19·31	5·03	5·05	7·08	6·95	7·09	6·96	0·13	0·04	÷ 0·08
7 b	19·47	5·15	5·20	7·06	7·01	7·09	7·04	0·05	0·05	0·01
D.W.	0·00	10·21	10·29	7·45	7·86	7·49	7·91	÷ 0·42	÷ 0·30	0·12
1 a	3·37	10·21	10·26	7·37	7·51	7·41	7·55	÷ 0·14	÷ 0·13	0·02
2	7·77	10·23	10·31	7·10	7·21	7·14	7·26	÷ 0·12	÷ 0·06	0·06
4	11·63	10·31	10·38	6·90	6·91	6·95	6·97	÷ 0·02	0·04	0·06
6	15·72	10·54	10·61	6·27	6·51	6·36	6·61	÷ 0·25	÷ 0·24	0·01
7 a	19·31	10·28	10·38	6·29	6·12	6·33	6·17	0 16	0·01	÷ 0·14
D.W.	0·00	15·25	15·30	7·06	6·94	7·10	6·98	0·12	0·09	÷ 0·03
1 a	3·35	15·57	15·62	6·72	6·67	6·81	6·76	0·05	0·00	÷ 0·04
2	7·75	15·72	15·74	6·28	6·45	6·37	6·55	÷ 0·18	÷ 0·12	0·05
4	11·63	15·83	15·86	6·19	6·17	6·30	6·28	0·02	0·04	0·02
6	15·71	15·42	15·50	5·95	5·95	6·00	6·01	÷ 0·01	0·02	0·03
7 a	19·31	15·55	15·60	5·69	5·70	5·75	5·77	÷ 0·02	0·02	0·03
D.W.	0·00	20·13	20·12	6·46	6·42	6·48	6·43	0·05	0·08	0·04
1 b	2·74	20·33	20·36	6·13	6·23	6·17	6·27	÷ 0·10	÷ 0·07	0·04
2	7·76	20·58	20·64	5·90	5·76	5·96	5·83	0·13	0·02	÷ 0·12
4	11·64	20·78	20·86	5·63	5·63	5·72	5·72	0·00	÷ 0·02	÷ 0·01
6	15·64	20·91	20·96	5·43	5·40	5·52	5·50	0·02	0·02	0·00
7 a	19·32	20·83	20·88	5·20	5·20	5·28	5·29	÷ 0·01	0·00	0·00
D.W.	0·00	24·88	24·86	5·92	5·89	5·91	5·88	0·03	0·02	÷ 0·01
1 b	2·73	25·16	25·15	5·76	5·74	5·77	5·75	0·02	0·02	0·00
2	7·78	25·42	25·43	5·44	5·40	5·48	5·44	0·04	÷ 0·02	÷ 0·06
4	11·64	25·59	25·59	5·22	5·21	5·27	5·26	0·01	÷ 0·02	÷ 0·03
6	15·74	25·68	25·66	5·01	5·05	5·07	5·11	÷ 0·04	÷ 0·01	0·03
7 a	19·34	25·68	25·66	4·83	4·82	4·89	4·88	0·01	÷ 0·01	÷ 0·02

Tabelle 7.

T =	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°
Cl = 0	10·06	9·79	9·52	9 27	9·03	8·80	8·58	8·37	8·17	7·98	7·79	7·62	7·46	7·30	7·15	7·01	6·87	6·74	6·62	6·50	6·39	6·28	6·18	6·08	5·99	5·89
1	9·96	68	42	17	8 93	71	49	28	08	90	72	55	38	23	08	6·94	81	68	56	44	33	23	12	03	93	84
2	85	58	32	08	84	62	40	20	00	82	64	47	31	16	01	87	74	62	50	38	27	17	07	5·97	88	79
3	74	48	22	8·98	75	53	31	11	7·92	74	56	40	24	09	6·94	81	68	55	44	32	22	11	01	92	83	74
4	63	37	12	88	65	43	23	03	84	66	49	32	17	02	88	74	61	49	38	26	16	06	5·96	86	77	69
5	53	27	02	78	56	34	14	7·94	76	58	41	25	09	6·95	81	68	55	43	32	21	10	00	90	81	72	63
6	42	16	8·92	69	46	25	05	86	67	50	33	17	02	88	74	61	49	37	25	15	04	5·94	85	76	67	58
7	31	06	82	59	37	16	7·96	77	59	42	26	10	6 95	81	67	54	42	31	19	09	5·99	89	79	70	62	53
8	20	8·96	72	49	28	07	88	69	51	34	18	02	88	74	60	48	36	24	13	03	93	83	74	65	56	48
9	10	85	62	40	18	7·98	79	60	43	26	10	6·95	81	67	54	41	29	18	07	5·97	87	77	68	60	51	43
10	8·99	75	52	30	09	89	70	52	35	18	02	88	73	60	47	35	23	12	01	91	81	72	63	54	46	37
11	88	64	42	20	00	80	61	43	26	10	6 95	80	66	53	40	28	17	06	5·95	85	75	66	57	49	40	32
12	77	54	32	11	7 90	71	52	35	18	02	87	73	59	46	33	21	10	5·99	89	79	70	61	52	43	35	27
13	67	44	22	01	81	62	44	26	10	6·94	79	65	52	39	26	15	04	93	83	73	64	55	46	38	30	22
14	56	33	12	7·91	71	53	35	18	02	86	72	58	44	32	20	08	5·97	87	77	67	58	49	41	33	24	17
15	45	23	02	81	62	44	26	09	6·93	78	64	50	37	25	13	02	91	81	71	62	52	44	35	27	19	11
16	35	13	7·92	72	53	35	17	01	85	70	56	43	30	18	06	5·95	85	75	65	56	47	38	30	22	14	06
17	24	02	82	62	43	25	09	6·92	77	62	49	35	23	11	5·99	89	78	68	59	50	41	32	24	16	09	01
18	13	7·92	72	52	34	16	00	84	69	55	41	28	16	04	93	82	72	62	53	44	35	27	19	11	03	4·96
19	02	81	62	43	25	07	6·91	75	61	47	33	21	08	5·97	86	75	65	56	47	38	29	21	13	06	4.98	91
20	7·92	71	52	33	15	6·98	82	67	52	39	25	13	01	90	79	69	59	50	41	32	24	16	08	00	93	85

Tabelle über die in ccm. bei 0° und 760 mm. gemessene Menge Sauerstoff, welche von 1 Liter Meerwasser von der atmosphärischen Luft absorbiert werden kann, wenn deren Druck allein, ohne Wasserdampf und Kohlensäure, 760 mm. ist.

Um die berechneten und beobachteten Werte zu vergleichen, ist in den beiden letzten Kolumnen der Tabelle 6 der Unterschied aufgeführt zwischen den observierten Sauerstoffmengen (*M*) und den aus obiger Tabelle berechneten Sauerstoffmengen bei der Temperatur und Chlormenge, bei der die Observation stattfand. Man sieht, dass die Differenzen der mit * bezeichneten Proben von derselben Grössenordnung sind, wie die Differenzen der anderen Proben. Daraus geht hervor, dass die absorbierte Sauerstoffmenge dieselbe ist, ob nun die Probe aus naturgemäss vorkommendem Meerwasser mit geringem Salzgehalt besteht, oder durch Verdünnung von Ozeanwasser durch destilliertes Wasser auf denselben Salzgehalt, wie den des naturgemäss vorkommenden, hergestellt ist. Man kann also daraus schliessen, dass die für die Sauerstoffmenge gefundenen Zahlen für alles in der Natur vorkommende Meerwasser gelten.

Schliesslich sollen einige ältere Bestimmungen für destilliertes Wasser und Ozeanwasser zum Vergleiche mit den hier gefundenen angeführt werden.

Temperatur	Destilliertes Wasser				Ozeanwasser		
	Winkler[1])	Dittmar[2])	Bohr und Bock[4])	Der Verfasser	Dittmar[3])	Tornöe[6])	Der Verfasser[5])
0	10·25	10·25	10 32	10·06	8·18	7·77	7·97
5	8·98	8 99	9·14	8·80	7·22	6·93	7·03
10	7·97	8·00	8·11	7·79	6·45	6·29	6·29
15	7·16	7·20	7·28	7·01	5 83	5·70	5·72
20	6·50	6·53	6·59	6·39	5·31		5·27
25	5·96	5·97	6·04	5·89	4·87		4·88

[1]) l. c. [2]) Report on the scientific Results of the Voyage of H. M. S. Challenger: Physics and Chemistry Vol. I, pg. 173. [3]) ibd. pg. 224. [4]) Oversigt over det kgl. danske Videnskabernes Selskabs Forhandlinger 1897, S. 609. [5]) Die Zahlen in dieser Kolumne sind für 19·5‰ Chlor berechnet; bei Dittmar ist keine Salzmenge von der untersuchten Probe angegeben. [6]) Den norske Nordhavsexpedition 1876—78 Chem. pg. 18.

Die in der obenstehenden Tabelle angeführten Werte sind mit Ausnahme derjenigen von Bohr und Bock durch Absorption von atmosphärischer Luft im Wasser gefunden worden, aber in der Regel findet sich in den ausgerechneten Tabellen die Menge angegeben, welche aus einer reinen Sauerstoffatmosphäre absorbiert werden würde. Um diese Zahlen auf Zahlen zu reduzieren, die mit den in Tabelle 7 aufgeführten vergleichbar sind, müssten sie mit dem Bruch multipliziert werden, welcher die Sauerstoffmenge in der Atmosphäre ausdrückt. Beim Ausrechnen sind dieselben Werte benutzt, wie in den genannten Abhandlungen: für Winkler's Zahlen 0·2096 und für die Dittmar's 0·209. Für Bohr und Bock's ist 0·208 benutzt. In Bezug auf Tornöe's Zahlen wird bemerkt, dass kein Salzgehalt angegeben ist, sondern bloss, dass das Meerwasser von einigermassen hohem spezifischem Gewicht war; auch wird nicht angegeben, ob der 760 mm. Quecksilberdruck für die Absorption, auf die die Zahlen reduziert sind, als mit oder ohne Wasserdampfdruck gelten soll.

Man sieht, dass man bei Winkler's Titriermethode in der hier benutzten Form etwas niedrigere Werte erhält, als bei der Auskochungsmethode. Indessen wird dieser Umstand ja ohne Bedeutung sein, wenn zu bestimmen gilt, wie viel dem Meerwasser zur Sättigung fehlt, und schliesslich ist der Unterschied ja nicht übermässig gross, sodass bei vielen praktischen Messungen kein Gewicht darauf zu legen sein wird. Wenn man also berücksichtigt, wie leicht anwendbar diese Methode ist, wenn viele aufeinander folgenden Bestimmungen ausgeführt werden sollen, lässt sich annehmen, dass sie mit Vorteil wird angewendet werden können, wenn von Sauerstoffanalysen in grösserem Stile die Rede ist.

Zum Schlusse sage ich Herrn Docent Knudsen noch meinen besten Dank für das Wolwollen, mit dem er mir oft bei der Arbeit geholfen hat.

550 28/VI 1905